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CONTENTS

Fusarium crown and root rot, and Sclerophoma stem blight, of the Texas bluebell ..... *J. J. Taubenhaus and Walter N. Ezekiel* 503

Three new cuscutas ..... *T. G. Yuncker* 511

Angiosperm phylogeny on a chemical basis ..... *James B. McNair* 515

The Nipissing flora of the Apostle Islands region ..... *L. R. Wilson* 533

Euphorbia capitellata, its synonymy and range ..... *Louis C. Wheeler* 537

Index to American Botanical Literature 539

Index to Volume 62 551

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Fusarium crown and root rot, and Sclerophoma stem blight, of the Texas bluebell[1]

J. J. Taubenhaus and Walter N. Ezekiel

(with two text-figures)

The Texas bluebell, *Eustoma russellianum*, is a native perennial growing in low meadows in calcareous soils in many sections of East and North Central Texas. In recent years, the Texas bluebell has been taken into cultivation in limited areas near some of the larger cities of Texas, yet market supplies of the blooms of this plant are still limited. Many florists who have attempted to grow this plant have become discouraged on account of attacks of various diseases. There is, ordinarily, little or no loss from disease in new plantings. Diseases appear usually during the second year and become progressively worse as the plants are grown continuously in the same place. For instance, a grower of Dallas, Texas,[2] started out in 1931 with about a thousand Texas bluebells and experienced no loss from disease during that year. But by the end of the next year, 80 per cent of the plants were dead. Plantings of Texas bluebells near San Antonio, Houston, and Beaumont have similarly shown annual losses from disease of only 15 to 30 per cent in new plantings, while in the older plantings losses ranged from 50 to 100 per cent.

It may be noted that in a wild state, Texas bluebells suffer relatively little from diseases. Large colonies of these plants have been examined near Madisonville. In 1932, of 500 plants examined, 3.5 per cent were dead or in a dying condition; and in 1933, of 500 plants examined, 5.3 per cent were dead or dying.

Of the several diseases of the Texas bluebell plant only two have been given attention.

I. Fusarium crown and root rot

Seedlings as well as older Texas bluebells develop a destructive crown and root rot. In the early stages of this disease, watersoaked areas appear on the crown of the plant, just above the surface of the ground. These areas enlarge, become depressed, and extend downward into the roots, which soften and decay. Meanwhile, the tops of the plants wilt, collapse, and die. During moist weather, the crowns of diseased plants become covered with scattered pinkish masses of *Fusarium* spores. Affected plants

[1] Published with the approval of the Director as Contribution No. 303, Technical Series, Texas Agricultural Experiment Station.

[2] The writers are indebted to Mr. G. M. Soxman, of Dallas, Texas, who has provided material for these studies, and has carried out the program of experimental spraying.

[The Bulletin for November (62: 433–565) was issued November 1, 1935]

succumb usually within a few days and rarely if ever recover from this disease.

Plants giving evidence of this disease were received first in 1931 from plantings at Dallas, Texas. Cultures were made from small, surface sterilized portions of infected root and stem tissues. *Fusarium*, *Trichoderma*, *Rhizoctonia*, and *Alternaria* were recovered from the infected root and stem material. Pure cultures of each fungus were grown on potato-dextrose agar slants and used to inoculate five normal Texas bluebell plants growing in steam-sterilized soil in 4-inch pots, while a similar number of plants in other pots were left as uninoculated checks. The entire fungus growth in two agar slants was placed next to the crown of each plant to be inoculated and covered with moist non-absorbent cotton. Plants inoculated with the *Fusarium* succumbed (fig. 1, a), reproducing typical crown and root rot; while the non-inoculated check plants, and those inoculated with *Trichoderma* or *Alternaria*, remained healthy. The plants inoculated with *Rhizoctonia* developed deep cankers, at the foot of the plant, quite unlike the root and crown rot caused by the *Fusarium*.

The *Fusarium* thus proved to cause crown and root rot of Texas bluebells was identified as *Fusarium solani*, and this identification verified by Dr. C. D. Sherbakoff. *Fusarium solani* has already been shown to cause in Texas a crown and root rot of spinach,[3] and a serious crown and corm decay of freesias.[4]

II. SCLEROPHOMA STEM BLIGHT

The second and more important disease of Texas bluebells is a stem blight which may occur also on the leaves. This trouble was found prevalent in every planting of Texas bluebells under cultivation near Dallas, Houston, and San Antonio, Texas. It attacks mature as well as young plants and is much more destructive during the second year than during the year following planting.

Stem blight becomes evident at the crown of the plant involving the main stem, and at the same time usually produces independent small, whitish, depressed lesions on the leaves and lateral branches of the plant. On leaves, the lesions usually enlarge; but if numerous they remain small and coalesce. Damage to the leaves is unimportant compared to the injury to the main stem. Here the infection rapidly spreads upward from the crown, and meanwhile extends around the stem. As the stem is gir-

[3] Taubenhaus, J. J. 1926. Studies of a new *Fusarium* wilt of spinach in Texas. Texas Agr. Expt. Sta. bull. 343: 5–23.

[4] Taubenhaus, J. J., and Ezekiel, Walter N. 1933. *Fusarium* wilt and corm rot of freesias. Botan. Gazette **95**: 128–142.

dled, first the lower leaves of the plant wilt, and within a few days all the leaves have wilted, whitened, and begun to shrink (fig. 1, c and d). Within three to ten days of infection, numerous scattered pycnidia appear as dark

Fig. 1. Inoculation experiments with Texas bluebell plants; a, inoculation with *Fusarium solani*, left, uninoculated plant, and right, one inoculated plant; and b, right to left, progressive decline of plants inoculated with *Sclerophoma eustomonis;* c, early and d, advanced stage of plants naturally infected by *Sclerophoma* blight; e, pycnidia of *S. eustomonis* appearing on stem of naturally infected plant; f, cultures of *S. eustomonis* in Petri dishes of potato-dextrose agar.

specks on the diseased areas, first near the crown, and then progressively upward along the main stem and laterals (fig. 1, e). Pycnidia are rarely found on the leaves although the fungus has been isolated successfully from the whitish lesions on the leaves. When placed in a moist chamber,

the spores ooze out from the pycnidia as small irregular creamy tendrils or droplets.

After the top of the plant has succumbed, new shoots sprout from below the injured portion, grow into sound stems, and may even yield a crop of blooms. Ultimately, these secondary shoots are attacked and killed

TABLE 1

Inoculation of Texas bluebells with Sclerophoma eustomonis.

(Plants growing in 4-inch pots in steam sterilized soil, 1 plant per pot, 5 plants per series).

DATE OF INOCULATION	INOCULUM	METHOD OF INOCULATION	PER CENT INFECTION AFTER 3 WEEKS
2–23–33	Suspension of pycniospores of *Sclerophoma eustomonis* from an infected stem of a Texas bluebell plant	Spores sprayed with atomizer on leaves and stems. Inoculated plants kept for 12 hours under moist bell jars	100[1]
—	Check	Not inoculated	0
4– 5–33	Suspension of pycniospores of *Sclerophoma eustomonis* from a pure culture growing on sterilized Texas bluebell stems	Spores sprayed with atomizer on leaves and stems. Inoculated plants kept for 12 hours under moist bell jars	100[1]
do	Pure culture of *Sclerophoma eustomonis* isolated from an infected stem of a Texas bluebell plant	Two tube cultures worked into soil around each plant, then covered with non-absorbent cotton	80[1]
—	Check	Not inoculated	20[2]
5– 2–33	Pure culture of *Sclerophoma eustomonis* recovered from *Pseudococcus maritimus* insects secured from an infected bluebell plant	Two tube cultures worked into soil around each plant, then covered with non-absorbent cotton	80[1]
—	Check	Not inoculated	0

[1] Organism recovered from 2 of the inoculated plants in each series.

[2] One check plant showed lesions and pycnidia of *S. eustomonis* on a small branch.

also. Usually no more new shoots are produced, and the roots of the plants are now attacked by various other organisms, particularly *Fusarium solani*.

Cultures made from bits of infected leaf or stem tissue yielded uniformly pure cultures of a fungus identified by Dr. C. L. Shear as a species of *Sclerophoma*.

A number of normal 3-months-old Texas bluebell plants growing in

pots in steam-sterilized soil were inoculated with a pure culture of this *Sclerophoma*. The methods of inoculations and the results are indicated in table 1. The typical stem and leaf blight was successfully reproduced by

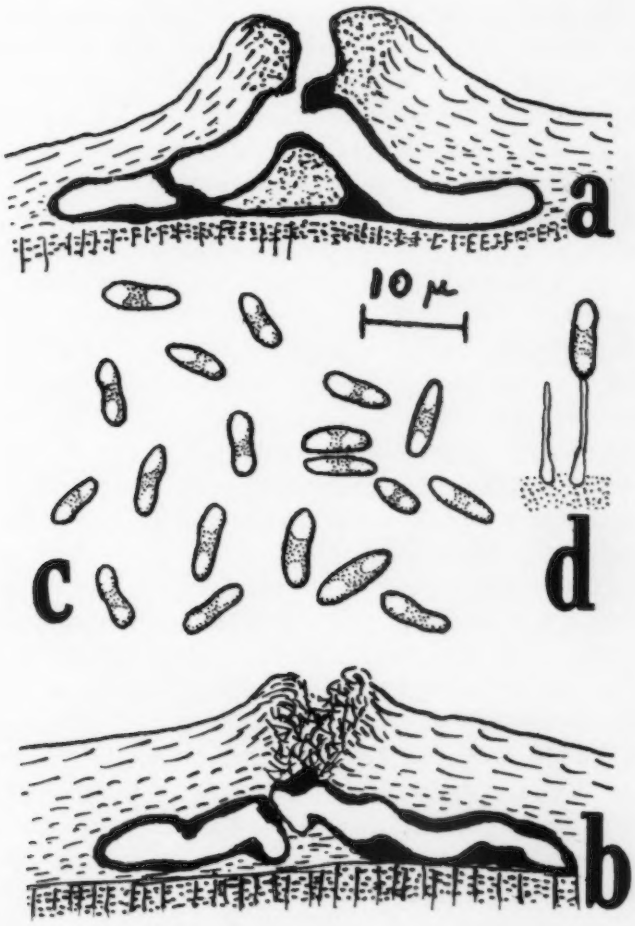

Fig. 2. a and b, sections of pycnidia of *Sclerophoma eustomonis* (diagrammatic); c, individual pycniospores; d, pycniospore attached to conidiophore. (a and b drawn by L. B. Loring, c and d drawn by Ezekiel)

all methods of inoculation, while almost all of the check plants remained normal (fig. 1, b).

The *Sclerophoma* sp. which affects Texas bluebells appears to be a new species, and the name *Sclerophoma eustomonis* Taubenhaus and Ezekiel was tentatively given to this organism.[5,6]

Sclerophoma eustomonis Taubenhaus and Ezekiel, sp. nov. Pycnidia dark, flattened, lenticular, imbedded, in a stromatic layer in host cortical tissue; 135 to 300μ in diameter, by 85 to 145μ in depth. Some with pycnidial wall only slightly irregular, forming single locules; others with the wall quite irregular and extensively lobed, dividing pycnidia into several locules, separated by the heavy folds of the pycnidial wall, as shown in figure 2, a and b. Conidia borne on small sporophores with extremely minute, nearly invisible, tips (fig. 2, d). Spores cylindric, 1-celled; hyaline, almost always with two conspicuous droplets, one near each end of spore, occasionally with only a single droplet near center of spore (fig. 2, c); mean size $6.8\times2.46\mu$, range $4.5-8.7\times2.1-3.1\mu$.

Fungi pycnidiis in lamellis stromatibus in hospitis thallo immersis; fuscis, applanatis, lenticulatis, uniploriloculatis; 135–300μ crassis, 85–145μ altis. Conidiophorae parvulae, apiculatae; conidia cylindracea, continua, hyalina, saepe 2-guttulata; $4.5–8.7\times2.1–3.1\mu$; vulgo $6.8\times2.46\mu$.[7]

The fungus is readily isolated and grows rapidly on potato-dextrose agar. Colonies are at first thin, somewhat fluffy and whitish, but after two weeks become flat, compact, brown and leathery, with the lower surface distinctly wrinkled. After about three weeks, dark brown stromatic pycnidial clumps begin to appear on the surface of Petri dish or tube cultures (fig. 1, f) and mature in six to ten weeks.

The fungus is parasitic on Texas bluebells. Type material and pure cultures of the fungus have been deposited with the Centraal-Bureau voor Schimmelcultures and with the United States National Museum.

Sclerophoma stem lesions frequently occur on the peduncles or on the seed pods of the affected plants. The seeds of Texas bluebells are minute and shatter readily as soon as the seed pods mature and dry. For this reason, the seed pods are harvested in a somewhat green condition, and allowed to dry in paper sacks. At planting time the pods are broken by hand, and infected seed pod tissue may thus become mixed with the seed. To check the possibility of the disease being carried in this way, unscreened and unsterilized seeds from Texas bluebell plants infected by *Sclerophoma* blight were planted in steam sterilized soil. The resultant plants were isolated and protected from chance infection, yet 140 of about 500 seedlings developed *Sclerophoma blight*.

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[5] Taubenhaus, J. J., and Ezekiel, W. N. On a new root rot and stem blight of Texas bluebells, *in* Texas Agr. Expt. Sta. Ann. Rept. 45: 77. 1932. (in this report, the name of the fungus was misspelled as *Sclerophoma customonis*).

[6] Taubenhaus, J. J., and Ezekiel, W. N. Check list of diseases of plants in Texas. Trans. Texas Acad. Sci. **16**: 5–89, 101–118. (p. 31) 1933.

[7] The writers are indebted to Dr. O. M. Ball for preparing this Latin diagnosis.

Texas bluebell plants are commonly attacked by a mealy bug identified as *Pseudococcus maritimus*.[8] Over three hundred mealy bugs were secured directly from plants affected also by *Sclerophoma* blight. The insects were transferred carefully with sterilized forceps to Petri dishes of potato-dextrose agar. Pure cultures of *Sclerophoma* were recovered from 4 per cent of the mealy bugs thus cultured, and the fungus successfully inoculated on normal Texas bluebell plants. Viable *Sclerophoma* spores were recovered also by centrifuging, in sterilized water, mealy bugs secured from infected plants. These results support the conclusion that mealy bugs may spread *Sclerophoma* blight by pycniospores which adhere to the bodies of these insects. Red spider, *Tetranychus bimaculatus* Harw., also attacks bluebell plants and may be concerned in spread of this disease.

CONTROL OF SCLEROPHOMA BLIGHT

Mature seed pods were secured from naturally infected bluebell plants. The seed pods were then broken up, and the minute seed were screened out and separated from the pod debris. The seed were dipped for 5 minutes in a solution of 1–2000 bichloride of mercury in 25 per cent alcohol, and planted in steam-sterilized soil. No disease appeared on the young seedlings from the seed thus treated. On the other hand, considerable *Sclerophoma* blight appeared on a number of the seedlings from the screened seed that was not disinfected, and on those from the seed that was neither screened nor disinfected.

A number of spraying programs were tested by Mr. G. M. Soxman of Dallas, Texas. During 1931, the plants were sprayed with 4-4-50 Bordeaux with little success. This was explained by the natural gloss of the plant which prevented adherence of the spray. During 1932, casein was added which increased the adhesiveness of the Bordeaux, but gave only slightly better control. During 1932, casein and also nicotine sulphate were added to the Bordeaux. This combined fungicide and insecticide adhered well and reduced *Sclerophoma* blight to 20 per cent in the sprayed plants, while unsprayed plants were practically a total loss.

During 1930, Mr. Soxman made successful crosses of Texas bluebells from North and South Texas. Of the twenty-five plants raised, twenty-four had typical large leaves and were susceptible to *Sclerophoma* blight. The remaining plant had narrow leaves and appeared resistant to stem and leaf blight. Progeny of this plant continue to maintain high resistance to *Sclerophoma* blight, but some of the strains have produced abnormal sterile plants.

[8] Identified by Dr. C. A. Weigel, of the Bureau of Entomology, U. S. Department of Agriculture.

SUMMARY

Attempts by florists to grow the Texas bluebell under cultivation have been disappointing because of the attacks of numerous diseases. The present paper deals with two of these diseases. A crown and root rot of seedlings and older plants was proved due to *Fusarium solani*. A second and more destructive disease is a stem blight caused by *Sclerophoma eustomonis* n.sp., a description of which is given. Mealy bugs (*Pseudococcus maritimus*), were proved capable of spreading the causal organism. Sclerophoma is carried by fragments of infected pods mixed with the seeds, and sterilizing the screened seeds lowered infection. A combination spray of Bordeaux, nicotine sulphate, and casein gave fair control of the blight. A strain of Texas bluebells with narrow leaves has shown high resistance to *Sclerophoma* blight, but has not yet been stabilized as to horticultural characteristics.

TEXAS AGRICULTURAL EXPERIMENT STATION,
COLLEGE STATION, TEXAS

Three new cuscutas

T. G. YUNCKER

(WITH ONE TEXT-FIGURE)

Cuscuta yucatana n. sp.

Caules tenues. Flores circ. 2 mm. longi. Pedicellati aequantes aut longiores quam flores. Calycis lobi triangulari-ovati, acuti. Corollae lobi oblongo-lanceolati, acutissime acuti, aequantes aut longiores quam corollae tuba campanulata, apices plus aut minus inflexi. Scalae oblongae aut plus aut minus spatulatae. Filamenta tenua aut plus aut minus subulata et longiora quam antherae oval-ellipticae. Styli tenui, aequantes aut longiora quam ovarium depresso-globosum. Capsula globoso-depressa, obovoida, non circumscissilis, corolla marcescens circum partem inferiorem. Semina 0.8–1.0 mm. longa.

Stems slender. Flowers about 2 mm. long, soon appearing larger because of the developing capsule, on pedicels as long as or more commonly somewhat longer than the flowers, in compound, umbellate cymes. Calyx longer than the corolla tube, lobes triangular-ovate, acute, not overlapping at the base. Corolla lobes oblong-lanceolate, very sharply acute, upright in young flowers, tips inflexed, soon becoming reflexed about the developing capsule, as long as or more commonly longer than the campanulate tube, more or less granular-papillate. Filaments slender to slightly subulate, mostly two to three times as long as the oval-elliptical anthers. Scales oblong or slightly spatulate, reaching the stamens, fringed with medium length processes, bridged at about one-fourth their height. Styles equal to or longer than the depressed-globose ovary. Capsule globose-depressed, more or less obovoid, comparatively large and bulging about the enclosed seeds, not circumscissile but thin towards the base and when torn away leaving the obcordate dissepiment in the calyx, withered corolla remaining about the lower part; seeds generally four in each capsule, mostly 0.8–1.0 mm. long, oval, hilum slightly oblique.

This species belongs in Subsection Acutae of Section Cleistogrammica with those species having acute flower parts and in which the capsules do not open by a definite circumscission. It would seem to be best placed between *C. globosa* Ridley of Brazil and *C. acuta* Engelmann of the Galapagos Islands. From *C. pentagona* Engelmann and *C. campestris* Yuncker it differs because of the longer pedicels and consequently less compact inflorescences, as well as by the acute calyx lobes. It appears to be most closely related to *C. acuta* but differs from that species chiefly in its smaller flowers and longer pedicels, as well as in the shape of its capsules.

SOUTHEASTERN MEXICO: Valladolid, Yucatan, *W. C. Steere*, July 2, 1932 (*No. 1695*), the type, in the Field Museum of Natural History.

Cuscuta deltoidea Yuncker var. **serrulata** n. var.

Calycis lobi serrati et plus aut minus acuti. Corollae lobi inserrati aut serrati.

The calyx lobes of this variety are coarsely and irregularly serrated and are somewhat more pointed than those of *C. deltoidea*. The corolla lobes are entire or shallowly and irregularly serrated. Otherwise this variety closely resembles the species.

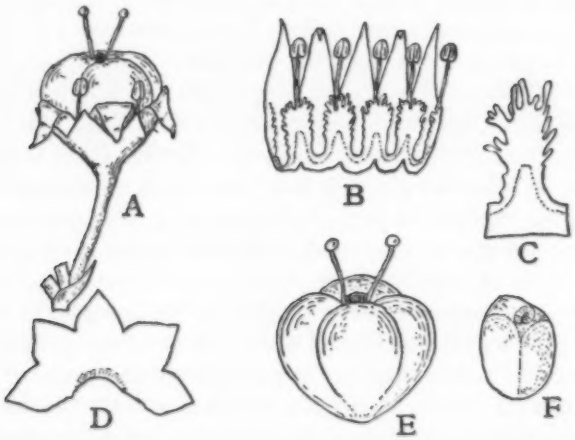

Fig. 1. *Cuscuta yucatana* n. sp. A, flower ×6; B, opened corolla ×6; C, individual scale ×12; D, opened calyx ×6; E, capsule ×6; F, seed ×10.

The size of the flowers, the shape of the calyx lobes, the length of the stamens, which are about as long as the corolla lobes, and characteristics of the flowers in general more closely ally this variety with *C. deltoidea* than with *C. gracillima* Engelmann. The shape and proportion of the calyx and corolla lobes distinguish it from *C. lacerata* Yuncker.

WESTERN MEXICO: Manzanillo, State of Colima, *C. R. Orcutt*, Oct. 20, 1919, the type, in the Field Museum of Natural History. (This is also the type locality of *C. deltoidea*.)

Cuscuta Suksdorfii Yuncker var. **subpedicellata** n. var.

Flores sessiles aut subsessiles, 2.0–3.0 mm. longi. Calycis lobi triangulari-acuti, longiores quam corollae tuba, breviores quam stamina. Capsula globosa aut globoso-depressa.

Flowers sessile or subsessile, 2–3 mm. long. Calyx lobes triangular, acute, exceeding the corolla tube, but not exceeding the stamens. Capsule globose or depressed globose.

The flowers of *C. Suksdorfii* are mostly definitely stalked and with the calyx lobes long, slenderly attenuated, and generally extending much beyond the stamens, and with capsules globose to ovoid.

NORTHERN CALIFORNIA: Siskiyou Mts., Siskiyou County, Head of E. Fork Horse Creek, 6500 ft. alt., on *Calyptridium umbellatum*, *Louis C. Wheeler*, Aug. 21, 1934 (*No. 3192*), the type: One mile E. Dry Lake Lookout, 6000 ft. alt., on the same host species, *Louis C. Wheeler*, July 31, 1934 (*No. 3011*). Both specimens in the writer's herbarium.

DePauw University,
Greencastle, Indiana

Angiosperm phylogeny on a chemical basis

JAMES B. MCNAIR

(WITH FIVE TEXT-FIGURES)

It is proposed in this paper to consider some phylogenetic theories relating to the angiosperms in the light of chemical analysis. Plants can be classified chemically in accordance with the substances made by them. Such a chemical classification may be compared with or used as a supplement to morphological classification and may be of some importance in the development of the true natural system of angiosperm phylogeny.

USE OF CHEMICAL FACTORS IN THE STUDY OF PHYLOGENY

In this paper some physical and chemical properties of alkaloids, glycerides (fats) and volatile oils are used in the comparison of plant families and orders as well as in the comparison of different plant groups, e.g. the monocotyledons with the dicotyledons. In a previous publication (McNair, 1934) it has already been shown, first, that the more closely plants are related, the more closely similar are their chemical products; and second that the more highly evolved the plant (according to the Engler and Gilg classification) the larger are the molecules of its chemical products provided that the plants grow in the same climate. These findings will be made use of here in further comparisons of angiosperm phylogeny.

The chemical findings produce further information as to both the Bessey and the Engler and Gilg systems of classification. They show that in the glycerides the iodine numbers increase with the evolution in plant groups such as orders, etc. Space does not permit the inclusion here of all the tables from which the data in this paper were obtained. The average molecular weights for the alkaloids of the various plant families, the average familial iodine numbers of the glycerides, the average familial specific gravities of the volatile oils and the average refractive indices of the volatile oils used in this paper were secured from McNair (1934).

The arrangement of families and orders in the Bessey system is to be found in Bessey (1914), and the arrangement of families and orders in the Engler and Gilg system has been taken from Engler and Gilg (1919).

In the discussion of results obtained in this paper from tables Nos. 3 to 6 inclusive, the first column on the left includes all the tropical families from which data have been obtained, while the other columns include only part of these families. Therefore the left hand column gives a better average value founded on a larger group of plant families than any of the other columns. The figures in it can consequently be considered as more representative and dependable than those in the other columns.

The alkaloids increase in molecular weight in proportion to their increase in plant evolution (McNair, 1934). This is strikingly shown in the present paper in the consideration of Magnoliaceae vs. Ranunculaceae, herbs vs. trees, dicotyledons vs. monocotyledons, polypetaly vs. gamopetaly, and polycarpy vs. oligocarpy.

In apocarpy vs. syncarpy, the results do not coincide with those obtained by the use of the glycerides and volatile oils. In this instance, however, there is only a slight difference between the alkaloid values, e.g. 333 vs. 308 is 7.5%.

In the study of volatile oils, the specific gravities show that these values increase in general with plant evolution in the small as well as in the large plant groups. The refractive indices, however, decrease as evolution increases. This is in accordance with the general rule previously developed (McNair, 1932) that a lowering in the index of refraction carries with it an accompanying increase in the specific gravity.

ARE THE MAGNOLIACEAE PRE-RANUNCULACEAN?

Hallier (1905a, b) believed that the Ranunculaceae and Nymphaeaceae are descended from the Magnoliaceae through the Schizandraceae, Lardizabalaceae and Berberidaceae.

Engler, however, has concluded that it is not likely that such characteristically woody families as the Magnoliaceae and Lauraceae have arisen from herbaceous ancestors, or vice versa, but that these woody types have had a quite different origin from the herbaceous Ranunculaceae, as have most of the monocotyledons whose protangiospermous ancestors may be assumed to have been herbaceous (Campbell, 1930).

Volatile oils have been found in the Ranunculaceae, alkaloids in the Ranunculaceae and Berberidaceae, and glycerides in the Ranunculaceae, Berberidaceae and Lardizabalaceae. All three of these families are found for the most part in the temperate zone and consequently they can be successfully compared chemically. The accompanying table 1 shows that the values of the alkaloids diminish from the Ranunculaceae to the Berberidaceae; and that the values of the glycerides diminish correspondingly

TABLE 1

Are the Magnoliaceae pre-ranunculacean?

FAMILY	DOMINANT FORM	ALKALOIDS (MOL. WT.)	GLYCERIDES (IOD. NO.)
Magnoliaceae	Shrub-Tree	—	95.5
Lardizabalaceae	Shrub	—	78.4
Berberidaceae	Herb-Shrub	330	139.1
Ranunculaceae	Herb	543	145.0

from the Ranunculaceae, through the Berberidaceae to the Lardizabalaceae. Consequently, Hallier's theory of descent has chemical support as far as chemical data are available.

The Ranunculaceae consist mainly of herbs, the Berberidaceae of herbs and shrubs, and the Lardizabalaceae of shrubs. Here there is an indication that shrubs may precede herbs phylogenetically.

The Magnoliaceae are mainly a sub-tropical family and therefore can not be compared chemically with the three temperate zone families considered here. The average iodine number of the glycerides of the Magnoliaceae, 95.5, should be lower than the temperate glycerides and higher than the tropical glycerides in order to comply with the general rule. Assuming that the Magnoliaceae are plants of the temperate zone as are the three other families, their low value, 95.5, would indicate that they are more primitive than the Berberidaceae and Ranunculaceae.

ARE HERBS DERIVED FROM TREES?

The foregoing chemical results indicate that herbs may be derived from trees. Eames (1911), in a paper devoted to the subject, brings forward evidence that the earliest dicotyledons possessed a solid tubular woody cylinder of considerable thickness which has gradually been reduced, and finally broken up into a circle of separate strands, which is characteristic of the "typical" herbaceous condition. Such an hypothesis of reduction from primitive arborescent forms has also been worked out under the direction of Professor Jeffrey by several other members of his laboratory (Adkinson, 1913, Bailey, 1911, and Jeffrey, 1912). In more recent papers, Sinnott and Bailey, (1914, 1922), produced evidence in support of this view from palaeobotany, phylogeny, anatomy and geographical distribution. It is no wonder then that Bessey (1915) included in his "General principles adopted for the classification of plants" the postulate that "in certain groups, trees and shrubs are probably more primitive than herbs."

This hypothesis may be considered from the standpoint of the chemical products derived from plants. In table 2, the glycerides, alkaloids, and volatile oils from tropical plant families are considered in this respect.

From the final average obtained of the molecular weights of the alkaloids, there is a clear indication that trees produce alkaloids of lower molecular weights than shrubs, and that shrubs have lower alkaloid averages than herbs. Corresponding results are obtained from the iodine numbers of glycerides. The average refractive indices and specific gravities of volatile oils in respect to the dominant form of plant growth in the families is also developed in table 2. Here again the findings clearly indicate that trees may be the ancestors of herbs. This is shown in the specific gravities.

It has been observed that volatile oils with a high specific gravity have a correspondingly low index of refraction, (McNair, 1932). If then the specific gravities of volatile oils decrease from herbs to trees, the refractive indices should increase from trees to herbs. This is the case as shown by the averages (table 2). There is chemical support, therefore, for the contention of Bessey (1915), Sinnott and Bailey (1914), and others, that in the angiosperms herbs have been derived from woody plants.

TABLE 2

Are herbs derived from trees?

HERBS	HERBS-SHRUBS	SHRUBS	SHRUB-TREES	TREES
		Alkaloids (mol. wt.)		
307	231	236	348	191
		Glycerides (iod. no.)		
117	102	96	94	66
		Volatile oils (sp. gr.)		
.8875	.9340	.9010	.9175	.8878
		Volatile oils (ref. ind.)		
1.4904	1.4918	1.4295	1.4938	1.4630

The chemical data used in table 2 are taken from McNair (1934). The following families used in the calculations are considered as consisting mainly of trees: Bombacaceae, Caricaceae, Dipterocarpaceae, Lecythidaceae, Moringaceae, Palmae, Rhizophoraceae, and Winteranaceae; the families consisting mostly of shrubs and trees are, Anacardiaceae, Annonaceae, Araliaceae, Bignoniaceae, Bixaceae, Burseraceae, Caryocaraceae, Cochlospermaceae, Combretaceae, Ebenaceae, Erythroxylaceae, Flacourtiaceae, Guttiferae, Hernandiaceae, Lauraceae, Meliaceae, Monimiaceae, Moraceae, Myristicaceae, Myrtaceae, Ochnaceae, Olacaceae, Oleaceae, Proteaceae, Salvadoraceae, Sapindaceae, Sapotaceae, Simarubiaceae, Staphyleaceae, Symplocaceae, Tiliaceae, Vochysiaceae, and Zygophyllaceae; mostly shrubs, Apocynaceae, Asclepiadaceae, Humiriaceae, Loranthaceae, and Vitaceae; the families consisting mostly of herbs, shrubs and trees, Loganiaceae, Menispermaceae, Phytolaccaceae, Rubiaceae, Sterculiaceae and Verbenaceae.

DO DICOTYLEDONS PRECEDE MONOCOTYLEDONS?

In the history of the development of taxonomic systems, there is a difference of opinion among different authors as to the precedence of the monocotyledons or the dicotyledons in the natural system. John Ray (1704), de Jussieu (1789), Eichler (1883), Engler and Prantl (1887–1909), Rendle (1925), Johnson (1931), considered monocotyledons as the antece-

dents of dicotyledons. The following botanists have believed dicotyledons to be the forbears of monocotyledons: de Candolle (1813), Bentham and Hooker (1862–1883), Wettstein (1901), Bessey (1915), Hallier (1905a, b) Clements (1914), Jeffrey (1917), Hutchinson (1926).

Bessey's (1915) phylogenetic postulate is that dicotyledons are more primitive in origin than monocotyledons. Chemical results indicate, however, that the monocotyledons precede the dicotyledons. For instance the alkaloids show by their molecular weights larger averages (table 3), e.g.

TABLE 3

Do dicotyledons precede monocotyledons?

SUB-CLASS	ALL TROPICAL FAMILIES	HERBS, HERBS-SHRUBS	SHRUBS-TREES, AND TREES
	Alkaloids (mol. wt.)		
Monocot.	230	273	144
Dicot.	306	254	222
	Glycerides (iod. no.)		
Monocot.	63.62	80.98	28.9
Dicot.	85.85	109.40	77.92
	Volatile oils (sp. gr.)		
Monocot.	.9031	.9431	.8230
Dicot.	.9166	.9118	.9179
	Volatile oils (ref. ind.)		
Monocot.	1.4739	1.4978	1.4261
Dicot.	1.4877	1.4851	1.4945

306 and 222 for the dicotyledons and respectively 230 and 144 for the monocotyledons. This is in agreement with the finding (McNair, 1934) that the more highly evolved plants produce compounds of higher molecular weights. In table 3, the iodine numbers of the glycerides are higher in the dicotyledons than in the monocotyledons, being respectively 85.85, 109.40 and 77.92 in the dicotyledons and 63.62, 80.98 and 28.90 in the monocotyledons. The specific gravities of the volatile oils (table 3) give corresponding results which are confirmed in part by the converse values of the indices of refraction.

Families in the monocotyledons and dicotyledons are given according to the Engler and Prantl system. The chemical data used are from McNair (1934). The families of the monocotyledons and dicotyledons are grouped according to the predominance in them of herbs, shrubs and trees: herbs; herbs and shrubs; shrubs and trees; and trees. The names of these families and their groupings are given above under the section, "Are herbs derived from trees?"

TABLE 4

Polypetaly versus gamopetaly

GROUP	ALL TROPICAL FAMILIES	HERBS AND HERBS-SHRUBS	SHRUBS-TREES AND TREES
	Alkaloids (mol. wt.)		
Axiflorae			
Polypet.	333	287	355
Gamopet.	308	188	0
Calyciflorae			
Polypet.	159	0	197
Gamopet.	374	0	0
	Glycerides (iod. no.)		
Axiflorae			
Polypet.	82.57	136.16	76.63
Gamopet.	84.40	103.70	70.79
Calyciflorae			
Polypet.	95.19	112.5	92.31
Gamopet.	110.77	0	0
	Volatile oils (sp. gr.)		
Axiflorae			
Polypet.	.9179	.9091	.9158
Gamopet.	.9229	.9354	0
Calyciflorae			
Polypet.	.9076	.8700	.9236
Gamopet.	.9199	0	0
	Volatile oils (ref. ind.)		
Axiflorae			
Polypet.	1.4944	1.5015	1.4961
Gamopet.	1.4815	1.4688	0
Calyciflorae			
Polypet.	1.4662	0	1.4876
Gamopet.	1.4930	0	0
	Alkaloids (mol. wt.)		
Archichlam.	298.7	287	201
Metachlam.	321	188	352
	Glycerides (iod. no.)		
Archichlam.	82.98	124.25	76.77
Metachlam.	93.84	105.48	86.82
	Volatile oils (sp. gr.)		
Archichlam.	.9150	.8960	.9179
Metachlam.	.9224	.9354	0
	Volatile oils (ref. ind.)		
Archichlam.	1.4883	1.5015	1.4944
Metachlam.	1.4853	1.4688	0

POLYPETALY VERSUS GAMOPETALY

In his consideration of flower types, Bessey (1915) considers that "Free petals (polypetaly) are more primitive than connate petals (gamopetaly)."

The Bessey system divides both the axiflorae and calyciflorae into apopetalae (polypetalae) and gamopetalae. But in the Engler and Prantl classification the apopetalae are found in the archichlamydeae and the gamopetalae in the metachlamydeae.

This postulate of Bessey finds support in the chemical products of the polypetalae and gamopetalae. For instance, the glycerides (table 4) 82.57 vs. 84.40 and 95.19 vs. 110. 79; the alkaloids, 333 vs. 308, (show a difference of only 7.5%); the volatile oils give .9179 vs. .9229, 9091 vs. 9354, .9076 vs. .9199; 1.4944 vs. 1.4815, 1.5015 vs. 1.4688. In Engler and Prantl's system the archichlamydeae (apopetalae) are according to both phylogeny and chemical products more primitive than the metachlamydeae (gamopetalae). This is shown by the glycerides (table 4) 82.94 vs. 93.84, 76.77 vs. 86.82; by the alkaloids 298.7 vs. 321, and 201 vs. 352; by the volatile oils (specific gravity) .9150 vs. .9224 and .8960 vs. .9354, (refractive indices) 1.4883 vs. 1.4853 and 1.5015 vs. 1.4688.

POLYCARPY VERSUS OLIGOCARPY

Bessey (1915) advanced another postulate which finds chemical evidence in its favor. This postulate is that "many carpels (polycarpy) preceded few carpels (oligocarpy)."

TABLE 5

Polycarpy versus oligocarpy

GROUP	ALL TROPICAL FAMILIES	HERBS AND HERBS-SHRUBS	SHRUBS-TREES AND TREES
	Alkaloids (mol. wt.)		
Polycarpy	352	0	352
Dicarpy	294	188	0
	Glycerides (iod. no.)		
Polycarpy	88.04	0	88.04
Dicarpy	83.74	103.72	59.30

Bessey separates the polycarpellatae from the dicarpellatae in his gamopetalae. Chemical evidence for these divisions in the Bessey system is found only in the glycerides and the alkaloids (table 5). Neither the glycerides nor the alkaloids support the Bessey theory as shown by table 5: 88.04 versus 83.74 and 8804 versus 59.20 and 352 versus 294.

APOCARPY VERSUS SYNCARPY

In his consideration of the evolution of flower structure, Bessey (1915) states, "free carpels (apocarpy) are more primitive and from them connate carpels resulted; sometimes, however, when the carpels have remained loosely united during the evolution, they may again become quite free."

In Bessey's classification, the apopetalae have separate or united carpels, but the gamopetalae have united carpels only. Consequently, as has been shown above under "polypetaly versus gamopetaly," chemical evidence indicates that free carpels are more primitive (table 6).

TABLE 6

Apocarpy versus syncarpy

GROUP	ALL TROPICAL FAMILIES	HERBS AND HERBS-SHRUBS	SHRUBS-TREES AND TREES
	Alkaloids (mol. wt.)		
Apocarpy	333	287	355
Syncarpy (Gam.)	308	188	0
	Glycerides (iod. no.)		
Apocarpy	82.57	136.16	76.63
Syncarpy (Gam.)	84.40	103.70	70.79
	Volatile oils (sp. gr.)		
Apocarpy	.9179	.9091	.9154
Syncarpy (Gam.)	.9229	.9354	0
	Volatile oils (ref. ind.)		
Apocarpy	1.4944	1.5015	1.4961
Syncarpy (Gam.)	1.4815	1.4688	0
	Glycerides (iod. no.)		
Ranales	72.03	0	72.86
Rhoeadales	105.95	119.50	92.40

The Engler and Gilg system makes a clear separation of apocarpy from syncarpy in the Ranales (apocarpy) and Rhoeadales (syncarpy). Only glycerides have been analyzed in the Rhoeadales and no alkaloids or volatile oils. The glycerides, however, give favorable evidence to the theory e.g. (table 6) 72.03 versus 105.95 and 72.86 versus 92.40.

ENGLER AND GILG SYSTEM FROM A CHEMICAL STANDPOINT

The various divisions under the Engler and Gilg (1919) system of classification are divided for the purpose of this study into the following various sections such as the monocotyledons; A, the Amentiferae (from the Piperales to Urticales); B, Proteales to Polygonales; C, Centropermae;

D, Ranales to Umbelliflorae; A, Diapensiales to Plumbaginales; B, Ebenales; C, Contortae; and D, Tubiflorae to Campanulatae. These divisions or sections may be considered as radii originating from a central point thus forming a cart wheel design. This central point may be taken as zero and the positions of the various orders on the radii may be taken equal to the various chemical results obtained from a study of their glycerides, alkaloids, and volatile oils.

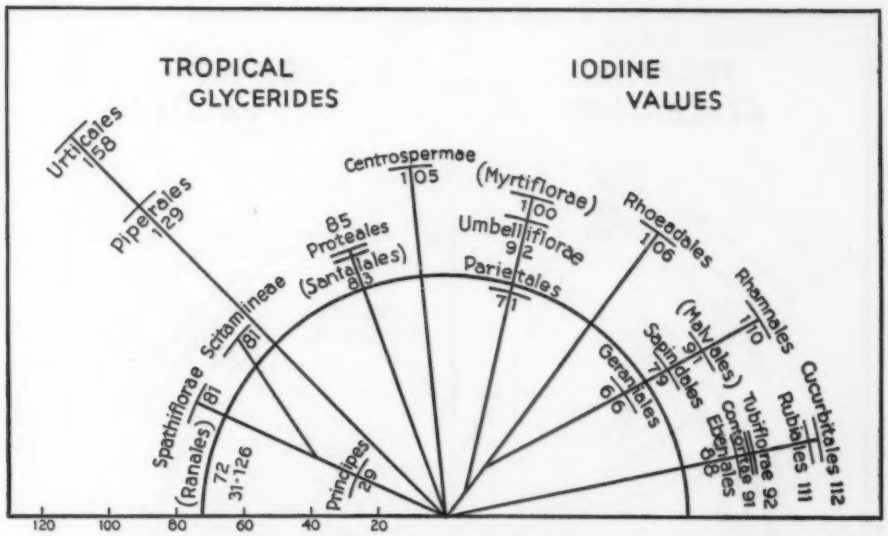

Fig. 1. A wheel-like arrangement of the orders of the Engler and Gilg system. Only those tropical orders containing glycerides are used here. The orders are placed, at distances from the axis that are equal to the average iodine absorption values of these glycerides. Each radius represents a section or branch of the Engler and Gilg phylogenetic system. Beginning from left to right there are: Monocotyledons, Amentiferae, Proteales, etc. The Ranales are represented on an arc for easy comparison with the other orders, for in the Bessey system the Ranales are the most primitive.

Glycerides. The iodine numbers of the glycerides (fig. 1) of the tropical families and sections of the Engler and Gilg system show in general a close agreement with the botanical classification. Complete agreement is found in the monocotyledonae, the amentiferae and in the metachlamydeae.

According to the Engler and Gilg phylogenetic system the Santalales are farther advanced than the Proteales. The iodine values however indicate the reverse to be true. Inasmuch as the chemical difference between them is very slight (Proteales 85 and Santalales 83) the chemical evidence is hardly sufficient to counteract the morphological evidence and phylogenetic position.

Likewise the chemical evidence here presented is probably too insignificant to warrant serious consideration for departure in phylogenetic position from Engler and Gilg classification, namely, that the Parietales 70.57 should phylogenetically precede the Ranales 72.03, or that the Geraniales 65.82 should precede the Ranales 72.03, or that the Sapindales 79.24 should precede the Malvales 90.65, or that the Umbelliflorae 91.8 should precede the Myrtiflorae 100.08.

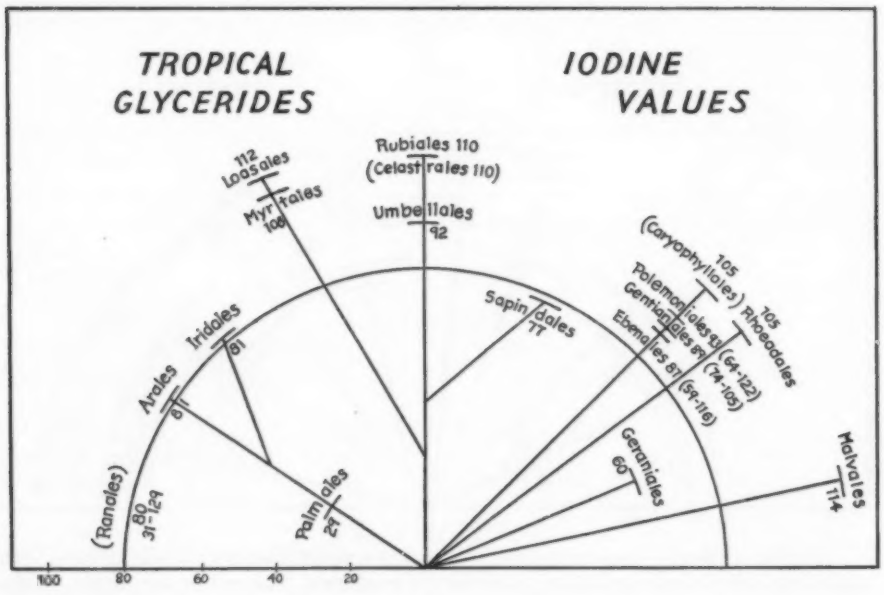

Fig. 2. A wheel-like arrangement of the orders of the Bessey system. Only those tropical orders containing glycerides are used here. The orders are placed at distances from the wheel axis that are equal to the average iodine absorption values of these glycerides. Each radius represents a section or branch of the Bessey phylogenetic system. Beginning from left to right there are the three main branches: Monocotyledoneae, Cotyloideae (cup flowers), and Strobiloideae (cone flowers).

Alkaloids. The molecular weights of the alkaloids of the tropical families and sections of the Engler and Gilg classification show in general a close agreement with the botanical classification. As in the case of the glycerides, complete agreement is found in the monocotyledonae, the amentiferae and in the metachlamydeae (except Tubiflorae). In the orders coming from the Ranales there is the usual disagreement between the Ranales and the rest of the group. The Myrtiflorae 197 are out of harmony with the Geraniales 238 and Parietales 239.

Volatile oils (*specific gravity*). The specific gravities of the volatile oils do not agree as well chemically with the Engler and Gilg botanical classification as do the glycerides and alkaloids. According to the chemical classification in the monocotyledons, the Scitamineae. 9225 precede the Spathi-

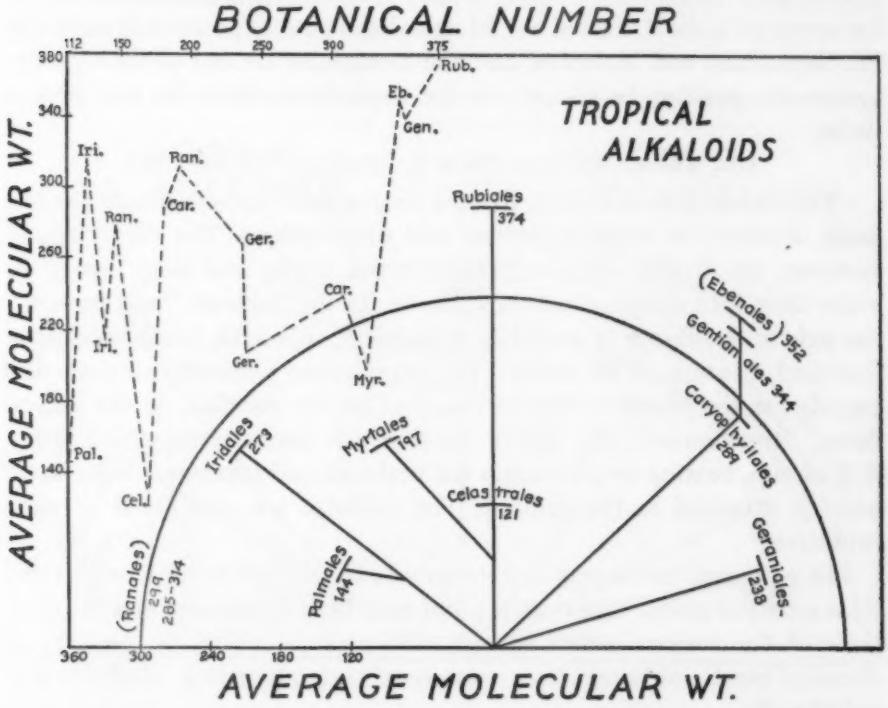

Fig. 3. A wheel-like arrangement of the orders of the Bessey system. Only those tropical orders containing alkaloids are used here. The orders are placed at distances from the wheel axis that are equal to the average molecular weights of the alkaloids of each order. Each radius represents a section or branch of the Bessey phylogenetic system. Beginning from left to right there are the three main branches: Monocotyledoneae, Cotyloideae (cup flowers), and Strobiloideae (cone flowers) . The Ranales are phylogenetically at the axis or base of the Bessey system but chemically they do not so appear.

The dotted lines represent the same data that are used on the wheel. They are arranged as a polygon whose coordinates are the average molecular weights and botanical numbers of the involved alkaloids (see McNair, 1934).

florae .964, in the amentiferae the Urticales .8633 precede the Piperales .9656, and in the metachlamydeae the Tubiflorae .9309 precede the Rubiales .9199. As usual the Ranales .9324 are out of harmony with some of the group that are said to come from them, i.e. Ranales .9324 versus Rosales .8722, Geraniales .9095 and Parietales .9167.

Volatile oils (*refractive index*). The refractive indices furnish data which are apparently in better agreement with the Bessey system than with the Engler and Gilg classification. The Ranales are out of harmony with the Engler and Gilg system but probably in better agreement with it than with their position in the Bessey system. The Piperales are not in harmony with the Urticales, the Rhamnales are out of position in regard to the Sapindales and Malvales, and the Geraniales are out of their proper systematic position in relation to the Sapindales, Malvales and Rhamnales.

THE BESSEY SYSTEM FROM A CHEMICAL STANDPOINT

The Bessey system (1914), like the Engler and Gilg, recognizes the two main divisions of monocotyledons and dicotyledons. The dicotyledons, however, are divided differently than in the Engler and Gilg. Bessey divides them into axiflorae and calyciflorae. In the axiflorae "axis flowers," the axis of the flower is normally cylindrical, spherical, hemispherical or flattened, bearing on its surface the hypogynous perianth, stamens and carpels (or the stamens may be attached to the corolla). In the calyciflorae, "cup flowers," the axis of the flower is normally expanded into a disk or cup, bearing on its margin the perianth and stamens (or the latter may be attached to the corolla). The axiflorae are considered as more primitive.

The groups of the Bessey system may be considered as radii originating from a central point. This central point may be taken as zero and the positions of the various orders on the radii may be taken as the various chemical results obtained from a study of their glycerides, alkaloids and volatile oils.

Glycerides. The iodine numbers of the glycerides (fig. 2) of the tropical families and sections of the Bessey system show in general a close agreement with the botanical classification. Only three of the orders do not agree with the botanical classification, viz., the Caryophyllales, Celastrales and Ranales. The Caryophyllales 105 should precede the Ebenales 87. The Celastrales 110 should precede the Umbellales 92. The Ranales 80 should be nearer the point of origin than any of the other dicotyledons.

Alkaloids. The molecular weights of the alkaloids (fig. 3) of the tropical families and sections of the Bessey classification show in general a close agreement with the botanical classification. But two discrepancies are noted. The Ranales 299 should precede all other dicotyledons, i.e. in this case they should have a lower number than 121. The Ebenales 352 should precede the Gentianales 344.

Volatile oils (*specific gravity*). Only one inharmonious order is found in this arrangement (fig. 4) and that is the usual case of the Ranales. The

Ranales .9308 should come before any of the rest of the dicotyledons, i.e., should have a lower number than .8722.

Volatile oils (*refractive indices*). As in the case of the specific gravities of the volatile oils, the Ranales are alone in not being in agreement with the botanical classification (fig. 5). The Ranales 1.5013 should be less than 1.429.

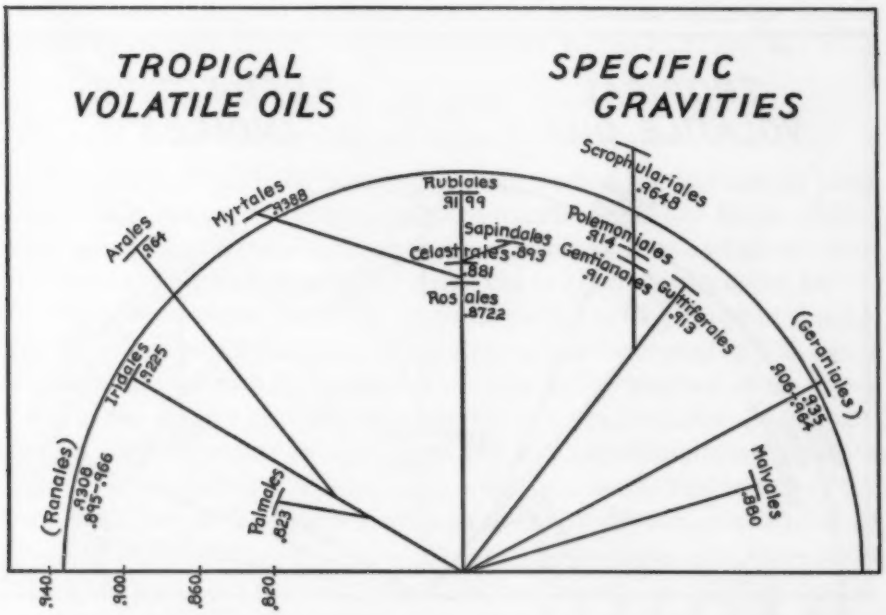

Fig. 4. A wheel-like arrangement of the orders of the Bessey system. Only those tropical orders containing volatile oils whose specific gravities have been determined are used here. The orders are placed at distances from the wheel axis equal to the average specific gravities of the volatile oils of each order. Each radius represents a section or branch of the Bessey phylogenetic system, beginning from left to right there are the three main branches: Monocotyledoneae, Cotyloideae (cup flowers), and Strobiloideae (cone flowers). The Ranales phylogenetically at the base or axis of the Bessey system are represented as on an arc and chemically not at the axis of the system.

DISCUSSION OF THE ENGLER AND GILG AND BESSEY SYSTEMS FROM A CHEMICAL POINT OF VIEW

The Engler and Gilg system considers that monocotyledons precede dicotyledons. The Bessey system on the contrary classes dicotyledons as coming before monocotyledons. The chemical evidence given in this paper supports the Engler and Gilg contention: that monocotyledons may have preceded dicotyledons (table 3).

With this exception both systems agree in their use of the following phylogenetic principles:

1. Polypetalous flowers are more primitive than gamopetalous ones.
2. Numerous carpels represent a more primitive condition than few carpels.
3. Separate carpels represent a more primitive condition than united carpels.

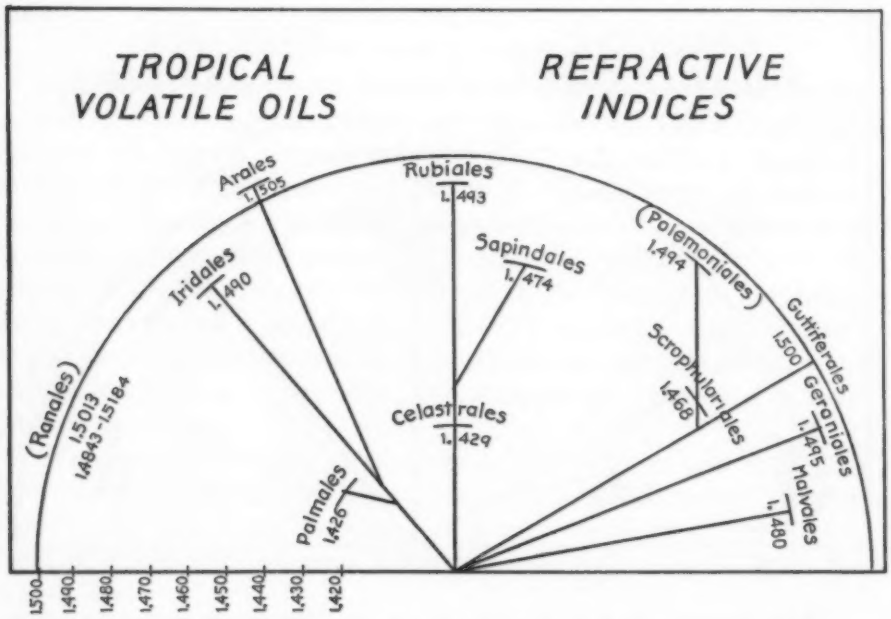

Fig. 5. A wheel-like arrangement of the orders of the Bessey system. Only those tropical orders containing volatile oils whose refractive indices have been determined are used here. The orders are placed at distances from the wheel axis equal to the average refractive indices of the volatile oils of each order. Each "spoke" or radius with its connections (arms) represents a branch of the phylogenetic tree of Bessey. Beginning from left to right there are the three main branches: Monocotyledoneae, Cotyloideae (cup flowers), and Strobiloidae (cone flowers). If one looked down upon a tree from its top the branches would appear to radiate from a common center. In a similar way the branches of the phylogenetic tree are here presented.

All of these, except no. 2, have been shown to hold true from the chemical investigations. In this case chemical evidence (table 5) indicates that few carpels may represent a more primitive condition than many carpels. The Bessey, and the Engler and Gilg systems, however, differ in the relative importance given to these phylogenetic principles.

In both systems the Ranales do not fall in the position allotted to them.

There is, however, better agreement with their position in the Engler and Gilg system than with their position in the Bessey system.

The Ebenales and Gentianales are out of harmony in the Bessey system (alkaloids, fig. 3). These are closer together in the Engler and Gilg system.

The Caryophyllales and Gentianales are far removed in the Engler and Gilg but may agree better with that classification than with Bessey's (glycerides, fig. 1).

The Celastrales and Umbellales do not harmonize with the Bessey system (glycerides, fig. 2). These are in better accord in Engler and Gilg.

PROTEINS VERSUS ALKALOIDS, GLYCERIDES AND VOLATILE OILS AS PLANT DETERMINANTS

Mez (1922, 1926) in his serum diagnostic method for determining plant relationship, makes use of protein plant constituents. The Moyer (1934) electrophoretic method also depends upon proteins for its usefulness. Both of these methods give serial plant sequences in plant classification, but do not show the relative evolutionary development of various plant groups, e.g. the palms versus the iris, or the palms versus the Rubiales. The use of the molecular weights of the alkaloids, of the iodine numbers of the glycerides, of the specific gravities or refractive indices of volatile oils give numerical values for plant groups, and in this way more definite comparative values for evolutionary appreciation are determined. For instance, the iodine numbers of the glycerides give for the palms (Principes or Palmales) 29, the iris (Liliiflorae or Iridales) 81, and the Rubiales 111. From these results the palms are the most primitive, the iris next and the Rubiales the most developed. The Rubiales may perhaps be considered as having developed four times farther than the palms, at least in their ability to produce unsaturated glycerides.

The use of proteins in plant determination requires the use of fresh material. This is often difficult to obtain for some groups. The use of alkaloids, glycerides and volatile oils does not require fresh material and thus has the advantage over the use of proteins.

SUMMARY

Some of the chemical products produced by plants are influenced by the climate in which they are formed. Fats (glycerides) produced in the tropics have lower iodine values than fats formed in temperate regions. Alkaloids found in tropical plant families have smaller molecular weights than those of the temperate regions. Volatile (essential) oils have lower specific gravities and higher refractive indices when formed in the tropics than when formed in a temperate climate. In other words it would seem

that more complex chemical products are formed in the temperate regions than are formed in the tropics.

When these three classes of substances appear in plants of the same climatic zone, e.g., in the tropics, the chemical properties vary with the degree of evolution of the plant according to the Engler and Gilg system. The highest evolved fats have the highest iodine values, the highest evolved alkaloids have the largest molecular weights, and the highest evolved volatile oils have the greatest specific gravities as well as the lowest refractive indices.

According to evidence obtained from the analyses of alkaloids, glycerides, and volatile oils formed by plants:

The Ranunculaceae may have been preceded by the Berberidaceae and Lardizabalaceae.

Herbs may have been derived from trees.

Monocotyledons may have preceded dicotyledons.

Free petal flowers (polypetaly) are more primitive than united petal flowers (gamopetaly).

Few carpels (oligocarpy) preceded many carpels (polycarpy).

Free carpels (apocarpy) may be more primitive than united carpels (syncarpy or gamocarpy).

These chemical findings may be used in comparing various systems of plant classification, e.g., the Bessey and the Engler and Gilg systems. The Bessey system considers dicotyledons as more primitive than monocotyledons. Chemical evidence does not support this view, but favors in this regard the Engler and Gilg classification. The other phylogenetic principles as listed in the preceding paragraph are used in both systems, although both consider many carpels more primitive than few carpels.

In both systems, according to the chemical evidence, the Ranales do not fall in the positions allotted to them. There is, however, better agreement with their position in the Engler and Gilg system.

The Ebenales and Gentianales are out of harmony in the Bessey system. These are closer together (both in Contortae) in the Engler and Gilg system.

The Caryophyllales and Gentianales of Bessey are far removed in the Engler and Gilg (being respectively Myrtiflorae and Contortae), and the chemical findings may agree better with that classification than with Bessey's.

The Celastrales and Umbellales do not harmonize with the Bessey system. These are in better accord with Engler and Gilg where the orders are considered as Sapindales and Umbelliflorae.

In the taxonomic revision of various plant groups, the serum diagnostic

method of Mez and the electrophoretic method of Moyer may give correct taxonomic sequences, but the use of alkaloids, glycerides and volatile oils gives not only these sequences but also (because they deal in numerical values) gives an idea as to the relative degree in evolution of various groups e.g. the palms versus the iris, or the palms versus the Rubiales.

The methods of Mez and Moyer require fresh material, while the alkaloids, etc., may be obtained from dried herbarium materials.

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The Nipissing flora of the Apostle Islands region

L. R. Wilson

In Science, February 13, 1931, a fossil flora of the Nipissing Great Lakes was briefly described by the writer. As was there stated, the plant remains are preserved in the form of rather extensive peat beds submerged in Lake Superior in the vicinity of the Apostle Islands, Bayfield County, Wisconsin. The samples, sent by Prof. J. A. Merrill, of the Superior State Teachers College, were recovered from beneath fourteen feet of sand and forty feet of water about one and one-half miles west of Sand Island, Bayfield County, Wisconsin. The geological significance of this deposit has been discussed by Dr. F. B. Taylor (Science **74:** 265–267, 1931.) and the formation of the peat set as contemporaneous with the original one-outlet stage of the Nipissing Great Lakes.

The botanical importance of this deposit becomes evident when one reviews literature dealing with the plant life associated with the Glacial Great Lakes. Two facts stand out, particularly: that the actual knowledge of the plants occurring at this period in the history of the Great Lakes is confined to one or more species of *Chara* (Coleman, A. P., Toronto University Studies, Biol. Sur. No. 21; 1922), and that much hypothetical dating of the appearance of certain Atlantic Coastal Plain plants and others in the upper Great Lakes Region, has been done, based entirely upon an interpretation of their present distribution (Peattie, D. C., Rhodora **24:** 57–70, 80–88; 1922., McLaughlin, W. T., Ecol. Mon. **2:** 335–383; 1932, and Anderson, E., Rhodora **35:** 154–160; 1933). The appearance of these Coastal Plain plants in the Great Lakes Region at an early post glacial date seems very probable, but only since the discovery of the submerged peat beds in Lake Superior is it possible to reconstruct a picture of the ecological conditions of early Glacial Lake Nipissing time and to state definitely what plants then existed in northern Wisconsin.

An examination of the largest sample of peat, which is approximately eighteen inches square and four inches thick, shows that it is of a type formed in comparatively still shallow water. About one-half of the thickness of the sample is made up of organic mud, throughout which occur fragments of plant and animal tissues. This portion of the sample is evidently a deeper water deposit than the other half which contains organic tissues in greater abundance and perfection. It seems reasonable to consider the latter as the upper side, but considering the history of the region it is impossible to state definitely.

The largest sample was separated arbitrarily into three horizons, and examined both macro- and microscopically for fossils. The horizon con-

taining the greatest percentage of organic mud and little plant tissue, is horizon No. 1, the middle horizon is No. 2, and that containing much tissue and little organic mud is No. 3.

The families, genera, and species of plants that have been recognized as fossils in the peat are listed below with their stratigraphic position. A pollen spectrum of the three horizons was also attempted and the table below is based on a count of one thousand fossils from each level.

Flora of the Nipissing peat

Sphagnum sp. (spores; in No. 3, stems and leaves) general.
Polypodiaceae sp. (spores) No. 3.
Lycopodium clavatum (spores) No. 1.
Taxus canadensis (wood) No. 1.
Pinus Strobus (pollen; in No. 1, cone) general.
P. Banksiana (pollen) general.
P. resinosa (pollen) general.
Larix laricina (pollen) No. 3.
Picea mariana (pollen) general.
Abies balsamea (pollen; in No. 1, cone scale) general.
Gramineae (pollen) general.
Cyperaceae (pollen) No. 1.
Carex crinita (leaves, rhizomes and possibly an achene of this species) Nos. 2 and 3. The distinctive markings on the sheaths made the identification of this species certain.
Salix sp. (pollen) No. 2.
Betula papyrifera (pollen) general.
B. pumila (pollen) general.
Alnus sp. (pollen) No. 1.
Quercus sp. (pollen) Nos. 1 and 2.
Acer spicatum (pollen) general.
Ericaceae (pollen of two genera) general.
Chamaedaphne calyculata (trichomes and leaves) general.
Compositae (pollen of four genera) general.

Percentage of microfossils in the Nipissing peat

SPECIES	HORIZON (1)	(2)	(3)
Sphagnum	1.4	34.2	16.0
Polypodiaceae	0.0	0.0	0.7
Lycopodium clavatum	0.5	0.0	0.0
Pinus resinosa and *P. Strobus*	16.6	8.3	34.1
P. Banksiana	7.2	14.4	17.0
Picea	45.3	6.0	16.1
Abies	9.5	4.1	4.2
Gramineae	5.4	2.4	1.4

Cyperaceae	0.6	0.0	0.0
Betula	10.1	24.1	6.0
Alnus	0.3	0.0	0.0
Quercus	1.1	0.6	0.0
Acer	0.4	0.4	0.5
Ericaceae	0.6	0.5	2.3
Compositae	1.0	5.0	1.7

An examination of the species recognized from the peat shows that they are typical of the Canadian Zone. Other studies upon peat deposits of pro- and post-Glacial Lake Nipissing age in northern Wisconsin (paper in preparation) show that there was a definite plant succession upon the area uncovered by the water in its drop from the Algonquin level to that of the Nipissing. This recorded succession in the peat deposits begins with an almost total percent of *Picea* and a small percent of *Pinus*. Slightly higher in the profiles, other components of the present flora appear. An unsuccessful attempt was made to fit the spectrum of the Nipissing peat into those of the other deposits studied. In spite of this it is definite that the Nipissing material does not record the pioneer vegetation of the region, and that the bottom layers of the submerged peat deposit were not collected. The species represented as fossils suggest that before the close of the one-outlet stage of Glacial Lake Nipissing, sufficient time had elapsed to allow the succession of plant communities to go far beyond the pioneer stage. For the development of a plant community, such as suggested by the fossils, several centuries, if not longer, must have elapsed.

The writer is indebted to Prof. J. A. Merrill, for the opportunity of examining this valuable deposit and to Dr. N. C. Fassett, of the Department of Botany, University of Wisconsin, for helpful criticism during the investigation.

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Cedar Rapids, Iowa

Euphorbia capitellata, its synonymy and range

LOUIS C. WHEELER

EUPHORBIA CAPITELLATA Engelm. ex Torr., Bot. Mex. Bound. 188. 1859.

Chamaesyce capitellata (Engelm.) Millsp., Field Mus. Pub. Bot. **2:** 408. 1916.

Euphorbia pycnanthema Engelm. ex Torr., Bot. Mex. Bound. 188. 1859.

Chamaesyce pycnanthema (Engelm.) Millsp., Field Mus. Pub. Bot. **2:** 411. 1916.

Euphorbia Chamberlinii Johnston, Proc. Cal. Acad. Sci. IV; **12:** 1066. 1924.

Euphorbia capitellata is extremely variable; habit from prostrate to erect; vesture from nearly glabrous to densely short pubescent; leaf shape from ovate to narrowly linear-lanceolate; leaf margin from entire to coarsely serrate. The most strikingly characteristic feature of this species is the bearing of the involucres in small heads but this character alone will not distinguish the species from some other Anisophyllae.

Examination of about a hundred sheets of this species from various herbaria has convinced me that only one species can be recognized even though it is a polymorphic entity. Also I have compared fragments (from the Field Museum, Chicago) of the types of *Euphorbia capitellata* and *E. pycnanthema* and they seem to be identical. It is interesting that Engelmann in the original description (q.v.) expressed a doubt that the two are distinct. The only definite difference in the two descriptions is that *E. capitellata* is annual and *E. pycnanthema* perennial. As the perennial members of *Euphorbia*, section Anisophyllum, subsection Chamaesyce bloom the first year it is impossible, with only one specimen, to be sure a species is annual. *E. capitellata* is the valid name by priority of position.

I have examined the type of *Euphorbia Chamberlinii* Johnston and it does not differ essentially from typical *E. capitellata*. The leaves are entire nearly throughout but many other specimens of *E. capitellata* have entire leaves. The type of *E. Chamberlinii* is heavily parasitized with white coccids which gives it a confusing appearance.

Euphorbia capitellata ranges from southern Arizona south into Lower California, Sonora, and Sinaloa, and east through Chihuahua and Coahuila. There is one collection doubtfully from California. See Bull. So. Cal. Acad. Sci. **31:** 105. 1934 for discussion of this.

EUPHORBIA CAPITELLATA Engelm. var. LAXIFLORA Wats., Proc. Am. Acad. **24:** 74. 1889.

Euphorbia gladiosa Jones, Con. West. Bot. **15:** 144. 1929. I have seen the type of *E. gladiosa* at Pomona College Herbarium and it is in no respect different. This variety is distinguished from the typical species by the very lax habit and the narrowly linear-lanceolate leaves. It is local about Guaymas, Sonora.

LA VERNE, CAL.

INDEX TO AMERICAN BOTANICAL LITERATURE

1931–1935

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

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INDEX TO VOLUME 62

New names and the final members of new combinations are in **bold face type.**

Abies 167, 534; Abies 227; balsamea 138, 148, 485, 487, 534
Abutilon Abutilon 227
Acer 251, 535; dasycarpum 482; pennsylvanicum 484, 487; rubrum 481; saccharinum 482, 484; saccharum 106, 360, 484; spicatum 534
Achillea Millefolium 485
Achlya 369
Aconitum 221
Acorus Calamus 481, 491
Acroporium 113
Acrostichum aureum 20
Actaea alba 481; rubra 481
Actea americana 481
Actinea herbacea 501
Actinomyces 421
Additional notes on tautonyms 227
Adhatoda Adhatoda 227
Adlumia fungosa 12
Aegilops 144, 497
Aesculus Hippocastanum 485
Agaricus campestris 498
Agave 148; Murpheyi 425
Aglaonema modestum 495
Agropyron pauciflorum 167; trachycaulum 167
Agrostemma Githago 485
Albuca fastigiata 135
Alchemilla 367, 547; canadensis 547
Alkaloids, The taxonomic and climatic distribution of 219
Alliaria Alliaria 227
Allium 376, 424; cepa 424; fistulosum 424, 493
Alloiosepalum 495
Alnus 534, 535; rugosa 481; serulata 481
Aloe ferox 64; hanburyana 135; Marlothii 64
Alseis 234
Alternaria 504; brassicae 233
Amanita phalloides 64
Amaryllis bifolius 406
Amelanchier canadensis 484
American Botanical Literature, Index to 59, 105, 165, 231, 291, 359, 421, 490, 539
Amoeba verrucosa 423
Amoreuxia 65
Amsonia 462
Anacamptodon splachnoides 6
Ananas Ananas 227, 230; comosus 230
Anatomy of the stem in the Lejeuneae, The 187, 259
Anemone canadensis 482; quinquefolia 480; virginiana 483
Anemonella thalictroides 480
Angiosperm phylogeny on a chemical basis 515
Anguloa brevilabris 431
Anoda cristata 363
Anomodon Toccoae 7
Anoplolejeunea 205, 206; conferta 203, 205, 207, 264, 276
Antennaria 499
Anthoceros laevis 296
Antitrichia curtipendula 198
Aphanolejeunea 261, 262; microscopica 259, 261, 262, 265, 267, 275, 276, 279
Aphanorhegma serrata 5
Aphyllon uniflorum 455, 457, 464
Aplanobacter Stewarti 62
Apocynum androsaemifolium 484
Apostle Islands region, The Nipissing flora of the 533
Apotettix eurycephalus 136, 149
Aquilegia canadensis 483
Arachis 223
Arachnion album 169
Aralia racemosa 481
Arariba 223
Araucarioxylon 366
Archilejeunea 198, 199; Spruceana 198, 199, 202, 276
Archimerus alternatus 143
Archontophoenix 540
Arctium lappa 485; minus 485
Arctostaphylos 105, 165
Arenaria 492; glabra 486; serphyllum 486; stricta 486
Ariocarpus 545
Arisaema Dracontium 394, 400; triphyllum 395, 399, 400, 480
Arisarum Arisarum 228
Aristolochia grandiflora 107
Armillaria mellea 169
Aronia botryapium 484
Ascaris megalocephala 133
Asclepias amplexicaulis 484; Cornuti 478; quadrifolia 484; syriaca 484
Ascochyta 242; Boltshauseri 499; viciae 361

Ascodesmis nigricans 175
Asilus 136; notatus 136, 148; sericeus 136, 148
Asparagus 6; officinalis 399
Aspergillus 90, 240, 365; niger 47, 81, 83, 87, 89, 90, 299; oryzae 495
Aspergillus niger, The nutritional requirements of the fungus 81
Aspidistra elatior variegata 165
Astelia 367, 498
Aster patens rosea 500
Astrodisculus araneiformis 431
Atamosco 403
Atractobasidium 340, 342, 495; **corticioides** 340
Atractobasidium, a new genus of the Tremellaceae 339
Atropa 222; Mandragora 229
Attalea Olssoni 60
Aucuba 549
Aulacomnium papillosum 59
Aureolaria virginica 484
Auricularia 342
Auriscalpium 546
Aveledoa 430
Avena 292, 313, 314, 317
AVERY, JR., GEORGE S., Differential distribution of a phytohormone in the developing leaf of Nicotiana, and its relation to polarized growth 313
Avicennia nitida 20
Azalea arborescens 486
Azara lanceolata 62
Azolla 366
Azotobacter 543

Bacillus radiobacter 168, 173; subtilis 241
Bacterium coli 57; Pruni 167; Syringae 233; typhosum 58
Balansia trinitensis 105
Baptisia tinctoria 484
BARNHART, JOHN HENDLEY, Dedicatory page, with portrait i; The published work of Elizabeth Gertrude Britton 1
Bartramia 5
Basidiobolus ranarum 370, 380
Basistemon 60
Batis 19–23; 25–27; maritima 20, 28, 235
Batis maritima L., The development of the shoot, male flower and seedling of 19
Battata 229; tuberosa 229
Befaria 495
Belamcanda chinensis 486
Bergerocactus emoryi 231
BERRY, EDWARD W., A fossil Cochlospermum from northern Patagonia 65
Beschorneria superba 135, 376
Besleria 496
Beta vulgaris 233
Betula 535; lenta 483; lutea 483; papyrifera 534; populifolia 484; pumila 534
Bibio hortulanus 145, 148, 372, 379
Bignonia trumpicans 485
Black Mesdag oats, Inheritance of resistance to loose smut in hybrids of Fulghum and 177
Blakeslee, A. F. and Sophia Satina, Fertilization in the incompatible cross Datura Stramonium×D. Metel 301
Bomarea 545
Botanical Literature, Index to American 59, 105, 165, 231, 291, 359, 421, 490, 539
Botrychium virginianum 430
Botryosphaeria ribis 112
Botrytis 50, 53, 58; cinerea 58, 418
Brachelyma robustum 8
Brachiolejeunea 202; insularis 202, 203, 205, 264, 276
Brachystola 134; magna 149
Brachythecium 297
Britton, The published work of Elizabeth Gertrude 1
Bruchia 5
Bryonia dioica 135
Bryophyllum calycinum 115
Bryophyta 5
Bryopteris 191, 192, 198; filicina 188, 190–193, 195, 264, 265, 275, 276
Bryoxiphium 6
Bryoziphium norvegicum 292
Bryum 5; proligerum 7
Buginvillea glabra 539
Bulbine annua 135
Bulbochaete 281, 282; **alpina** 281, 290; **areolata** 282, 290; brebissonii 283; **cimarronea** 282, 290; crassiuscula 282; crenulata 282; Furberae **depressa** 283, 290; gigantea 282, 283; intermedia 283; minuta 283; nana 283; Nordstedtii 283; obliqua 283; pygmaea 283; rectangularis 283; rectangularis hiloensis 283; repanda 284
Burnettia 8
Buxbaumia 6, 7
Buxella 129
Byrnesia Weinbergii 175

Calcitrapa Calcitrapa 229; stellaris 229
Caldesiella 546

Calendula 462
Calla palustris 481, 487
Callixylon Whiteanum 59
Calodon 546
Calopogon pulchellus 168
Caltha palustris 481
Calyptridium umbellatum 513
CAMP, W. H., Studies in the Ericales 1. The genus Gaylussacia in North America north of Mexico, 129
Campanula 462; americana 486, 488
Cannabis sativa 135, 395
Capsicum 79, 295, 360, 434, 444, 453, 454; annuum 75, 245, 433, 434, 449, 450, 452–454
Capsicum fruits, a genetic and developmental analysis, The factors governing shape and size in 433
Capsicum fruits, The inheritance of a geotropic response in 75
Cardamine 168, 367
Carex 548; crinita 534
Carica papaya 395
Carnegiea gigantea 107
CARTER, ANNETTA M., Riccia fluitans L.—a composite species 33
Carya 109; alba 483; amara 480; Buckleyi arkansana 294; cordiformis 480; ovata 483
CASSERA, JOSEPHINE D., Origin and development of the female gametophyte, endosperm and embryo in Orobanche uniflora 455
Castalia odorata 482
Castanea Castanea 228; dentata 483
Castilleia 234
Castilleja 362, 366
Catasetum maculatum 113
Catenaria 169
Catherinea 5
Caudalejeunea 204; Lehmanniana 203, 204, 205, 276
Ceanothus 547
Cedrus Cedrus 227, 228
Centaurea eriophora 229
Centrochloa 500
Cephaelia 223
Cephalanthes occidentalis 482
Cephalocereus polylophus 107
Cephalozia connivens 190, 270
Cerastium hirsutum 486; semidecandrum 486
Ceratiomyxa 294
Ceratodon 5
Ceratostomella Ulmi 499
Ceratozamia mexicana 133
Cercidium Torreyanum 429
Cercospora 110, 169; Rubi 55
Cercosporella 299
Cereus giganteus 498
Cetarach Cetarach 228
Chaetomium 119, 127
Chamaecyparis 131; thyoides 486
Chamaedaphne 427; calyculata 534
Chamaesyce capitellata 537; pycnanthema 537
Chara 533
Cheilophyllum 253, 428; dentatum 254, 256; **jamaicense** 254, 256; macranthum 254; **marginatum** 254, 255; micranthum 254, 256; **microphyllum** 254, 255; radicans 254; sphaerocarpum 254, 257; sphaerophyllum 257
Cheilophyllum of the West Indies, The genus 253
Cheilyctis 233
Chelidonium 222; majus 485
Chelone glabra 482
Chilopsis linearis 367
Chiloscyphus pallescens 262
Chimaphila umbellata 484
Chionodoxa lucillae 135, 376
Chlorella 62, 107; pyrenoidosa 107; vulgaris 236
Chlorococcum 234
Christisonia 464
Chromosome pairing in Yucca rupicola, A study of 133
Chromosome pairing to fertilization, The relation of 369
Chrysanthemum Leucanthemum 485
Cibotium 549
Cicedula divisa 239
Cicuta bulbifera 481; maculata 482
Cimicifuga racemosa 481
Cinchona 221, 223, 226
Cinclidotus fontinaloides 7
Circaea lutetiana 481
Cirsium altissimum 486, 488; arvense 485; lanceolatum 485
Citrullus vulgaris 491
Citrus 539; sinensis 502
Cladocera 399
Cladochytrium replicatum 494
Cladonia 294; pileolata 293
Cladosporium epibryum 2
Claytonia virginica 480
Cleistogamismus 92
Cleistogamy in Commelinantia Pringlei, Embryo sac development and 91
Clematis 430; virginiana 483

Clerodendron Thomsonae 12
Clethra alnifolia 11
Climacium 298; dendroideum 8
Clitocybe 218
Closterium 369
Clostridia 300
Coccoloba 174
Coccomyces hiemalis 59, 365
Cochlospermum 65, 67, 292; **previtifolium** 65, 66; vitifolium 67
Cochlospermum from Northern Patagonia, A fossil 65
Coenogonium Linkii 169
Coleus 326
Colletotrichum 361; phomoides 156, 163; truncatum 291
Collinsonia canadensis 481
Collybia 215, 217, 218, 425, 539; dryophila 216; platyphylla 216; **sedula** 218; velutipes 216
Collybia from Connecticut, A new species of 215
Colocasia 550; Colocasia 228
Cololejeunea 260, 261, 267
Colura 259, 260, 267; ornata 259, 265, 276
Commelina benghalensis 92; stricta 95, 99
Commelinantia 91, 92, 99, 100, 102; anomala 91, 93, 98; Pringlei 91, 92, 95, 98, 99, 101, 102, 297
Commelinantia Pringlei, Embryo sac development and cleistogamy in 91
Composite species, Riccia fluitans L.—a 33
Conium maculatum 485
Connecticut, A new species of Collybia from 215
Conophytum quarziticum 549
Convallaria biflora 480; latifolia 486; trifolia 485
Convolvulus repens 486; Sepium pubescens 486, 488
Coprinus micaceus 502; sterquilinus 298
Coptis trifolia 480, 487
Corallorhiza Corallorhiza 228
Cordaites missouriense 492
Cordia 106
Corema Conradii 2
Cornus 491; alba 482; canadensis 114, 484, 487; florida 484; stolonifera 482
Corticium 339, 341; nigrescens 339
Corydalis 222
Corylus americana 480
Corynanthe 223
Coryphantha 166, 365; columnaris 169
Coscinodon Raui 5; Renauldii 5
Costaea 495
Costus Tappenbeckianus 490
Cotinus Cotinus 228
Cotoneaster 63
Cotyledon orbiculata 546
Couma guatemalensis 494
Crataegus 69, 496; coccinea 486
Craterogyne 545
Cremosperma 496
Crepidula plana 346
Crepis 376, 500; biennis 490; capillaris 376; ciliata 490; syriaca 61
Crocodilium syriacum 229
Crocodylium Crocodylium 229
Cronartium ribicola 363
Cryptobranchus 146, 370, 377; allegheniensis 149, 374, 380
Cubeba Cubeba 228
Cucumis melo 62; sativus 168
Cucurbita 439, 444, 450, 454; Pepo 172, 246, 454
Culex 136, 137; pipiens 148
Cuphea 110
Cupressus 237; disticha 486; thyoides 486
Cuscuta 167, 174, 458; acuta 511; americana 483, 550; campestris 511; deltoidea 512; deltoidea **serrulata** 512; globosa 511; gracillima 512; Gronovii 62, 483; lacerata 512; pentagona 511; Suksdorfii 513; Suksdorfii **subpedicellata** 512; **yucatana** 511, 512
Cuscutas, Three new 511
Cyclolejeuna 206; chitonia 203, 206, 207, 276; convexistipa 203, 207, 276; peruviana 203, 207, 276
Cyclops 146, 147, 149, 370, 376–380; strenuus 376
Cydonia Cydonia 227, 228
Cypripedium arietinum 485, 487; pubescens 480
Cystolejeunea 210; lineata 208, 210, 264, 277
Cystopteris fragilis 541
Cystopus 369
Cytisus 331, 333, 335; scoparius 331, 332, 334, 501
Cytisus scoparius in Virginia with special reference to soil reaction, The natural distribution of 331
Cytological aspects of Grindelia species 69

Dadoxylon buitense 366
Dahlia 135, 136, 148

Damasonium Damasonium 227
Darluca filum 169
Dasyllis grossa 136, 148
Dasyscypha Pini 168
Datura 292, 301, 309, 310, 367; ceratocaula 301; laevis 304, 306, 307; Metel 301–306, 308–310, 312, 497; Stramonium 239, 301–310, 312, 346, 355, 485, 497; Tatula 307
Datura Metel, Fertilization in the incompatible cross Datura Stramonium×301
Datura Stramonium×D. Metel, Fertilization in the incompatible cross 301
Deamia testudo 429
Decachaena 129
Decamerium 129
Dedicatory page, with portrait i
Dentaria diphylla 481
Dentinum 546
Desmoncus 166
Development of the shoot, male flower and seedling of Batis maritima L., The 19
Developmental analysis of size and shape in tomato fruits, A 243
Dianthus Knappii 493
Dibotryon morbosum 108
Dicentra 222
Dicheirinia 423
Dichelyma 6
Dicranella heteromalla 5
Dicranolejeunea 204, 264; axillaris 203–205, 264, 275, 277
Dicranum 5
Dictyostelium discoideum 429
Diervilla Lonicera 483
Differential distribution of a phytohormone in the developing leaf of Nicotiana and its relation to polarized growth 313
Digitalis 450, 454
Dimorphandra 424
Dioscorea 291
Diplasiolejeunea 259, 260, 267; pellucida 259, 260, 265, 277; unidentata 259, 260, 262, 265, 276, 277
Dirca occidentalis 545
Dispira cornuta 490
Dissociation of Fusarium in soil, The 413
Ditrichum 5; Rhynchostegium 10
Dodecatheon 69
Dodge, B. O., A recessive factor lethal for ascospore formation in Neurospora 117
Dolichopterys 545
Draba 63; ruaxes 233
Dracaena 495
Dracunculus Dracunculus 228
Drepanolejeunea 213; inchoata 208, 213, 265, 277
Drosera rotundifolia 237
Drosophila 79, 148, 375, 378, 379, 387; melanogaster 78, 138, 145, 148, 149, 372, 374, 375, 379, 380
Dudleya 110
Dumortiera hirsuta 110
Duplications in Zephyranthes 403

Ecastaphyllum Ecastaphyllum 229
Ecastophyllum Ecastophyllum 229
Echeveria 432
Echinocereus 425; angusticeps 361; perbellus 491; Viereckii 114
Ectocarpus siliculosus 366
Ectropothecium 113; caroosiense 8
Effects of ultra-violet radiation and temperature on Fusarium I. Lethal action 45; II. Stimulation 151
Elateriospermum tapos 492
Eleocharis 299
Elytraria 109
Embryo sac development and clestogamy in Commelinantia Pringlei 91
Encalypta 5
Entosthodon Leibergii 7
Ephedra 43, 175, 238; antisiphilitica 421; antisyphilitica 43; pedunculata 43; texana 43; viridis 64
Ephedra from Western Texas, A new species of 43
Epicladium Boothianum 174
Epidendrum 291, 359
Epifagus virginiana 113
Epilobium 99, 308, 310; angustifolium 483, 487
Epipactis pubescens 483, 488
Epiphyllum 174
Equisetum 429; hyemale 484; littorale 3
Eragrostis Eragrostis 228
Ericales I. The genus Gaylussacia in North America north of Mexico, Studies in the 129
Erigeron 60
Eriogonum 544
Eriophora 229; Eriophora 229
Eriophyllum 106
Erpodium 8; domingense 112
Erysiphe 144; cichoracearum 168; graminis Tritici 171
Erythrina 223
Erythronium 421; americanum 480
Escherichia coli 156

Eschscholtzia 222
Escobaria 545
Espeletia 499
Eucalypta 5
Euchlaena 495
Eucomis bicolor 135, 376
Euglena deses 168
Eu-Lejeunea 212
Eu-Lussacia 129
Euosmolejeunea 211; trifaria 208, 211, 277
Eupatorium perfoliatum 482
Euphorbia 114, 532, 537; canariensis 106; capitellata 537; capitellata laxiflora 537; Chamberlinii 537; gladiosa 538; pycnanthema 537; ramipressa 106
Euphorbia capitellata its synonymy and range 537
Eurya 494
Euryanthe 65
Eusphaeralcea 494
Eustichia 4
Eustichium norvegicum 2
Eustoma russellianum 503
EVANS, ALEXANDER W., The anatomy of the stem in the Lejeuneae 187; 259
Evolvulus pilosus 297
Exidia 300, 342
EZEKIEL, WALTER N. AND J. J. TAUBENHAUS, Fusarium crown and root rot, and Sclerophoma stem blight, of the Texas bluebell 503

Factors governing shape and size in Capsicum fruits; a genetic and developmental analysis 433
Fagopyrum esculentum 485, 495
Fagus grandifolia 483
Felicia amelloides 168
Fertilization in the incompatible cross Datura Stramonium × D. Metel 301
Festuca sciurea 493; Tracyi 295
Filipendula Filipendula 228
Fissidens 5, 7, 11, 12; Donnellii 12; dubius 8; grandifrons 7
Flammula 430
Floral anatomy and probable affinities of the genus Grisebachiella, The 471
Fomes, Pini 172
Fontinalis 4, 6, 275; antipyretica 275, 279
Forsythia 462
Fossil Cochlospermum from northern Patagonia, A 65
Fouquieria splendens 363
Fragaria virginiana 483
Fraxinus americana 484; nigra 240, 482
Fremontia 107; mexicana 241
Fritillaria recurva 114; striata 114
Fucus 369
Fulghum and black Mesdag oats, Inheritance of resistance to loose smut in hybrids of 177
Funaria 5
Funkia 149; ovata 135; sieboldiana 134, 135
Fusarium 46–48, 52, 53, 55, 56, 164, 239, 297, 361, 367, 419, 430, 497, 503, 504, 547; annum 62, 293; Cepae 161; Eumartii 45, 151, 156, 161; niveum 298, 414, 415, 417, 418; oxysporum 231; solani 504, 505, 510; tracheiphilum 414; vasinfectum 414, 416, 417
Fusarium. I. Lethal action, Effects of ultraviolet radiation and temperature on 45; II. Stimulation 151
Fusarium crown and root rot, and Sclerophoma stem blight, of the Texas bluebell 503
Fusarium in soil, The dissocation of 413

Galega 223
Galium 108, 295; lanceolatum 484; multiflorum 108; tinctorium 481; trifidum 482
Galtonia candicans 134, 135, 146, 355, 372, 373, 376
Gammarus 451; chevreuxi 453
Ganoderma 422
Gastrodia 99
Gaultheria procumbens 484
Gaylussacia 129, 130, 360; baccata 129, 130, 484; baccata glaucocarpa 130; baccata leucocarpa 130; brachycera 129, 130; dumosa 129, 130, 486, 488; dumosa Bigeloviana 130; frondosa 129, 131, 132, 486, 488; frondosa **glaucophylla** 131, 132; frondosa **polycodioides** 131, 132; hirtella 130; mosieri 129, 130, 132; nana 129, 131, 132; orocola 129, 130, 132; tomentosa 129, 130; ursina 129, 130
Gaylussacia in North America north of Mexico, Studies in Ericales I. The genus 129
Gentiana Andrewsii albiflora 424; crinita 13
Genus Cheilophyllum of the West Indies, The 253
Georgia 5
Geranium Bicknellii 165; maculatum 481
Gerardia flava 484
Geum rivale 482; virginianum 483
Gibberella moniliformis 501
Gilia 62
Ginkgo 360

Glaucium 222
Globularia 462
Gloeosporium 421
Gloiodon 546
Glomerella cingulata 109
Glyceria 494
Gnaphalium Webbii 61
Gnomonia nerviseda 423; veneta 540
Godetia 99
Goethalsia 173
Gossypium 498
Gouinia 299
GRAFF, PAUL W., A new species of Collybia from Connecticut 215
Graphium Ulmi 233
Graptopetalum 543
Griffithsea bornetiana 111
Grimaldia 300
Grimmia 6; torquata 2
Grindelia 69–71, 73, 299, 300; arenicola 71–73; arizonica 71; comporum 71, 72; columbiana 71; decumbens 71, 72; Halli 71, 72; hirsutula brevisquama 71; humilis 71, 72; lanceolata 71, 72; maritima 71, 72; nana 71; oxylepis 72; perennis 71; procera 71, 72; rubricaulis elata 71, 72; rubricaulis platyphylla 71–73; squarrosa nuda 71
Grindelia species, Cytological aspects 69
Grisebachiella 472, 477; Hieronymi 471, 473, 474, 476, 478
Grisebachiella, The floral anatomy and probable affinities of the genus 471
Grusonia santamaria 60
Gymnoconia interstatialis 496
Gymnogongrus 362
Gymnosporangium globosum 296

Habenaria flava 485, 487; orbiculata 486, 487; psycodes 480
Habernaria fimbriata 480
Habranthus robustus 405
Halicystis 231
Hamamelis virginiana 484
Handeliodendron 297
Haworthia 106
Haynaldia 497
Hedeoma pulegioides 484
Hedera 251
Helenium **decurrens** 230; helenioides 230; Helenium 230
Helianthus annuus 175; tuberosus 294
Helminthosporium 361; erythrospilum 362; gramineum 166, 363; oryzae 501
Helosis 462
Hemerocallis flava 430
Hemispora 495; coremiformis 495
Hepatica americana 483
Hericium 546
Hesperaloë parviflora 139
Hesperoyucca whipplei 139
Heteranthera 502
Heterodera marioni 294
Heuchera hispida 241
Hibiscus syriacus 539
Hippuris vulgaris 486, 487
Holcus halepensis 135
Homalothecium 8
Hordeum vulgare 295
Hornemannia 298
Hosta caerulea 346, 349, 352, 354, 497
Hosta caerulea, with special reference to the divisions, Nuclear behavior in the tapetum of 345
HOUGHTALING, HELEN B., A developmental analysis of size and shape in tomato fruits 243
Houstonia caerulea 486, 487
Hugelia 62
HUME, H. HAROLD, Duplications in Zephyranthes 403
Huodendron 497
Hyacinthus orientalis 135, 376
Hyalopsora aspidiotus 297
Hydrocharis morsus-ranae 135
Hygrohypnum Nicholsii 543
Hygrolejeunea 210; cerina 208, 210, 264, 265, 277
Hymenodictyon 223
Hymenogaster 167
Hyoscyamus 222
Hypericum perfoliatum 485; perforatum 485
Hypnum calyptratum 2; revolutum 8
Hypodermella Hiratsukae 492
Hypoxis hirsuta 480

Iboza riparia 294
Idria columnaris 363
Ilex cornuta 549
Impatiens biflora 481; pallida 481, 499
Index to American Botanical Literature 59, 105, 165, 231, 291, 359, 421, 490, 539
Indigofera tinctoria 486
Inheritance of a geotropic response in Capsicum fruits, The 75
Inheritance of resistance to loose smut in hybrids of Fulghum and black Mesdag oats 177

Inula Helenium 485
Ipomoea 313
Iris 359, 425; versicolor 481; virginica 233
Isanthus branchiatus 484, 488
Isoetes macrospora 500
Ixia chinensis 486

Jagerinopsis 12; squarrosa 11
Johnson, Duncan S., The development of the shoot, male flower and seedling of Batis maritima L. 19
Juglans 109; cinerea 480; nigra 486, 488
Juncus effusus solutus 481
Juniperus cinerea 484; virginiana 484

KAISER, SAMUEL, The factors governing shape and size in Capsicum fruits; a genetic and developmental analysis 433; The inheritance of a geotropic response in Capsicum fruits 75
Kalanchoe daigremontiana 64
Kallstroemia 432
Kalmia angustifolia 482, 487; latifolia 486, 487; polifolia 482, 487
Krigia virginica 485

Lagenaria Lagenaria 228
Lagenidium 541
Lamium amplexicaule 485; purpureum 100
Larix laricina 481, 487, 534
Larrea tridentata 236
Lasiococcus 129; mosieri 132; orocola 130, 132
Leersia 5
Lejeunea 212, 213, 279; cavifolia 212, 272; flava 208, 212, 213, 264, 265, 267–269, 271–277, 279; inundata 208, 212, 213, 277; serpyllifolia 272
Lejeuneae, The anatomy of the stem in the 187; 259
Lemanea grandis 107
Lemna cyclostasa 294
Lens Lens 228
Leontodon autumnalis 355
Leontopodium Leontopodium 228
Lepidium latofolium 424
Lepidostrobus 291
Leptocolea 261; planifolia 259–261, 277; scabriflora 259, 261, 262, 265, 277
Leptolejeunea 214; elliptica 208, 214, 265, 272, 277
Leptopoda decurrens 230; helenioides 230; Helenium 230
Leptosiphon 462
Leptospermum 362
Leptostachya 229; carolinensis 229; Leptostachya 229
Leptostachys 229; Leptostachys 229
Lespedeza 108, 494
Leucobryum 5; minus 4
Leucodoniopsis 9
Leucodontopsis 9
Leucolejeunea 199; xanthocarpa 194, 198, 199, 202, 266, 277
Leucomium 113
Leucothoë 549
Levisticum Levisticum 228
Ligustrum vulgare 485
Lilaeopsis 497
Lilio-narcissus bifolius purpureus 405, 408
Lilium 149, 375, 376, 378; canadense 372, 378, 482; columbianum 236; longiflorum 138; philadelphicum 138, 485, 487; regale 168; superbum 485, 488; tigrinum 173
Limnanthemum 2
Limonium Limonium 228
Linaria vulgaris 485
Linum 335, 462; usitatissimum 60
Liquidambar 2
Listera ovata 135
Literature, Index to American Botanical 59, 105, 165, 231, 291, 359, 421, 490, 539
Lithospermum arvense 485
Littorella americana 237
Lobelia 335, 462; cardinalis 482; inflata 485; Kalmii 482
Local flora, Recent changes in the composition of a 479
Lonchocarpus 235
Lupinus 222; albus 364; citrinus 490; perennis 484, 488
Lycaste longiscapa 500
Lychnis dioica 135
Lycium 176; halimifolium 175
Lycopersicon Lycopersicon 227
Lycopersicum 229, 251, 454; esculentum 243, 247–250, 252; pimpinellifolium 243, 247–250, 252; Solanum-Lycopersicum 229
Lycopodium clavatum 534; complanatum 6; complanatum flabelliforme 238
Lycopus americanus 482; europeus 482
Lycosa 148
Lygodesmia juncea 174
Lysimachia quadrifolia 484

Macrosiphum pisi 366
Macrosporium 164, 361; tomato 161
Maesa hirsuta 501

Maianthemum canadense 483
Malachodendron pentagynum grandiflorum 490
Malaxis 490
Malus Malus 227
Malvastrum 549
Malvaviscus Conzattii 539; Malvaviscus 228
Mamillopsis-Cochemiea 296
Mammillaria 173; pyrrhocephala 166; saetigera 60
Mandragora 229; Mandragora 229
Manfreda maculosa 174
Mangifera indica 291
Manihot Manihot 228
Marasmius 539
Marsilea 169
Martiella 239
Martin, G. W., Atractobasidium, a new genus of the Tremellaceae 339
Mastigolejeunea 200, 201; auriculata 199, 200, 277
Mauchia hirtella 499
Maurandia 492
Maxillaria fucata 113
McNair, James B., Angiosperm phylogeny on a chemical basis 515; The taxonomic and climatic distribution of alkaloids 219
McVaugh, Rogers, Recent changes in the composition of a local flora 479
Medeola virginiana 480
Megaskepasma erythrochlamys 60
Melanthalia abscissa 496
Melilotus 61; alba 493
Melocactus 109
Mentzelia decapetala 106; oligosperma 106
Menyanthes 462; trifoliata 482, 487
Mercurialis annua 135, 136, 150, 241, 395
Mesembryanthemum aurantiacum grandiflorum 422
Mexico, Studies in the Ericales I. The genus Gaylussacia in North America north of 129
Microcachrys tetragona 497
Microdus 113
Microlejeunea 213; bullata 208, 213, 214, 262, 265, 272, 276, 277
Milesia 295; marginalis 110
Mimulus ringens 482
Mirabilis 498; jalapa 173
Mislaid mistletoe, A 337
Mistletoe, A mislaid 337
Mitchella repens 484
Mitella diphylla 484
Mitragna 223
Mnium 5, 7
Moina 399
Moldenke, Harold N., Additional notes on tautonyms 227
Mollia 60
Mollugo verticillata 172
Monarda 233
Monilia albicans 236
Monotropa uniflora 484
Moringa Moringa 228
Morus 149; indica 135, 136
Mouriria anomala 135, 137, 146, 149, 376, 380
Mucor stolonifer 56
Mucornella 546
Murraya 492
Muscari botryoides 135
Muscorum 64
Mycena 218
Mycobacterium Phlei 300
Myoporum 462

Naias marina 135, 544
Najas 547
Natural distribution of Cytisus scoparius in Virginia with special reference to soil reaction, The 331
Neckera 8
Nectria 176
Nelumbo Nelumbo 228
Neobesseya 545
Neolloydia 171
Neomammillaria 173; confusa 166; Hoffmanniana 240; Macdouglai 493
Nepeta Cataria 485
Nerine rosea 135
Neurolaena 297
Neurolejeunea 195, 264; Breutelii 194, 195, 263, 276, 277
Neurospora 118, 122, 125, 127, 128, 170, 362, 500, 542; crassa 117, 124, 170; sitophila 124; tetrasperma 117, 119, 124, 126, 128
Neurospora, A recessive factor lethal for ascospore formation 117
New species of Collybia from Connecticut, A 215
New species of Ephedra from Western Texas, A 43
Nicandra physaloides 135, 148
Nicotiana 222, 314, 315, 328, 490, 542; Langsdorfii 109; paniculata 169; phylesis 63; rustica-paniculata 169; sanderae 109; sylvestris 315, 320–324; tabacum 107, 172, 293, 296, 315, 322–324, 496

Nicotiana, and its relation to polarized growth, Differential distribution of a phytohormone in the developing leaf of 313
Nipissing flora of the Apostle Islands region, The 533
Nissolia Hintoni 238
Nitella 234, 237
Nolana 355
North America north of Mexico, Studies in the Ericales I. The genus Gaylussacia in 129
Notes on Texas phloxes 381
Nothofagus 166
Nuclear behavior in the tapetum of Hosta caerulea, with special reference to the divisions 345
Nutritional requirements of the fungus Aspergillus niger, The 81
Nymphaea advena 482
Nyssa aquatica 237; multiflora 481; sylvatica 481, 488

Oakesia sessilifolia 480
Oats, Inheritance of resistance to loose smut in hybrids of Fulghum and black Mesdag 177
Observations and experiments on sex in plants 387
Octodiceras Julianum 7
Odontia 491
Odontolejeunea 264; lunulata 203, 205, 207, 264, 275, 277
Oedocladium 281
Oedogoniaceae of Oklahoma including new species and varieties, The 281
Oedogonium 281, 284, 286, 369; armigerum 284; aster 284; bohemicum 284; borisianum 284; Boscii occidentale 284; Braunii 284; capitellatum 284; cardiacum 284; cardiacum carbonicum 284; cardiacum minus 284; concatenatum 284, 285; concatenatum hutchensiae 285; concatenatum **regulare** 284, 290; crassiusculum 285; crassiusculum arechavaletae 285; crassiusculum cataractum 285; crassiusculum idioandrosporum 285; crassum 285; crispum 285; crispum gracilescens 285; crispum granulosum 285; cryptoporum 285; cryptoporum vulgare 285; cyathigerum 285; cyathigerum ellipticum 285; echinospermum 285; exocostatum 281, 285; flavescens **minus** 285, 286, 290; **fuscum** 286, 290; giganteum 286; grande 286; grande angustum 286; Gunnii 287; Howardii 287; Howardii minus 287; illinoisense **oklahomense** 287, 290; intermedium 287; irregulare 287; irregulare condensatum 287; Landsboroughi 287; longicolle senegalense 287; macrandium aemulans 287; macrandium Hohenackerii 287; macrandium lundense 287; mexicanum 287; mitratum 287; multisporum 288; nebraskense 288; oblongum **sphaericum** 288, 290; oboviforme 288; **ouchitanum** 288, 290; paludosum parvisporum 288; paucocostatum 288; pithophorae 288; plagiostomum gracilius 288; princeps 288; Pringsheimii abbreviatum 288, 290; propinquum 287; pungens 289; pusillum 289; pyriforme 288; pyrulum 288; rigidium 289; Rothii 289; rufescens exiguum 289; rugulosum minutum 289; Sancti Thomae 289; simplex 288; sphaericum 288; **subglobosum** 289, 290; suecicum australe 289; tapeinosporum 289
Oenothera 99, 102; biennis 484; parviflora 486; pollicata 298
Omphalanthus 198, 264; filiformis 194, 196, 198, 263, 266, 277
Omphalodes Omphalodes 228
Ophiobolus graminis 425
Ophioglossum 6; Engelmanni 241; vulgatum 430
Opopanax Opopanax 228
Opuntia echinocarpa 231; erinacea 493; leptocaulis 20; Opuntia 228
Orchis flava 485
Origin and development of the female gametophyte, endosperm and embryo in Orobanche uniflora 455
Ormosia 222
Orobanche cumana 458, 464; gracilis 455, 460, 464; hederae 455, 460, 464; minor 455, 457, 458, 464; ramosa 458; uniflora 455, 456, 458, 460, 462, 463
Orobanche uniflora, Origin and development of the female gametophyte, endosperm and embryo in 455
Orthotrichum 4, 5; stellatum 13
ORTON, C. R., The dissociation of Fusarium in soil 413
Oryza sativa 135, 136, 148, 372
Osmorhiza longistylis 484
Ourouparia 223
Oxalis 297; Acetosella 486, 487; stricta 484
Oxycoccus Oxycoccus 230; quadripetalus 230

Panicum longifolium 497; variegatum 169

Papaver 222
Papillaria nigrescens 8; nigrescens Donnellii 8
Paramachaerium 362
Paratettix texanus 136, 149
Parkinsonia microphylla 429
PARKS, MABEL, Embryo sac development and cleistogamy in Commelinantia Pringlei 91
Parnassia 549; asarifolia 231
Paronychia argyrocoma 237
Parsonia 110
Patagonia, A fossil Cochlospermum from northern 65
Pedicularis 172; canadensis 481
Pedilospora dactylopaga 62
Pellaea compacta 542
Peltandra virginica 167
Penicillium 424; brevicaule hominis 242; digitatum 56; expansum 60; italicum 56; javanicum 109; Zukalii 544
Peniophora Allescheri 496
Pennell, Francis W., The genus Cheilophyllum of the West Indies 253
Penstemon hirsutus 485
Pentaclethra 222
Penthorum sedoides 482
Peronospora 369; viciae 239
Persea americana 230; Persea 230
Pestalotia 549
Petroselinum Petroselinum 228
Petunia 167, 542, 545
Phacelia californica 293; hispida 300
Phascum 6
Phaseolus vulgaris 171, 550
Phegopteris dryopteris 239
Philonotis 9, 543
Phlox 294, 381, 383; aspera 381; Drummondii 381, 382, 384, 386; Drummondii glabriflora 381–384; Drummondii tenuis 381; Drummondii villosissima 381, 382; Drummondii viscosissima 381; **glabriflora** 383, 384; pilosa 381, 382, 502; roemeriana 381, 384; tenuis 381, 384; villosissima 381–383
Phloxes, Notes on Texas 381
Pholiota polychroa 430
Pholisma arenarium 361
Phoradendron 337, 432; **auriculatum** 337, 338
Phragmites Phragmites 228
Phryma Leptostachya 229
Phycomyces 232
Phyllactinia 144
Phyllocactus 174
Phymatotrichum 299; omnivorum 424, 491
Physcomitrella patens 5
Physcomitrium 5; pygmaeum 12; turbinatum 7
Physocolea proboscoidea 262
Physostigma 223
Phytolacca americana 483
Phytomonas rhizogenes 168, 173; tumefaciens 168, 173
Phytophthora 428
Picea 534, 535; canadensis 234; mariana 534
Pilotrichella floridana 8
Pilularia 169, 498
Pimenta Pimenta 228
Pinus 146, 147, 376, 378, 379, 535, 542; balsamea 485; Banksiana 534; canadensis 483; contorta 294; palustris 172, 175; pendula 481; ponderosa 242; resinosa 483, 487, 534; rigida 483; Strobus 483, 534
Pisum 453; sativum 135, 146, 372, 376
Plagiochila asplenioides 190
Plantago arenaria 548; lanceolata 135
Plants, Observations and experiments on sex in 387
Plasmodiophora Brassicae 169
Platanus occidentalis 482
Platygloea 342
Platygyrium branchycladon 7; repens 7
Platymiscium lasiocarpum 238
Pleuridium 6
Pleurochaete squarrosa 239
Pleuroderris 171
Pleurotus corticatus 544
Pocillum 424
Podophyllum 376; peltatum 481
Pogonatum 5
Pogonia affinis 240
Polycodium 131; stamineum 131
Polygala 491
Polygonatum pubescens 480
Polygonum arifolium 481; commutatum 482; Persicaria 485; punctatum 481; sagittatum 481; scandens 483; virginianum 480
Polypodium vulgare 6
Polythrincium 300
Polytrichum 5
Pontederia cordata 482
Populus angulata 480; deltoides 480; dilatata 485; nigra italica 485; tremuloides 483
Poria Sumstinei 498
Porophyllum Porophyllum 230; ruderale 230
Portulaca oleracea 492
Posadasia 496; capulata 496; pyriformis 496
Potamogeton foliosus 61

Potamolejeunea 212; orinocensis 208, 212, 264, 277
Prunella vulgaris 485
Prunus 147; lanata 360; pennsylvanica 359; persica 363; serotina 484; virginiana 359, 483
Pseudococcus maritimus 506, 509, 510
Pseudo-Idaea 129
Pseudotsuga 542
Pteridium latiusculum 484
Pteridophyta 2
Ptychanthus 198; striatus 191, 193, 195, 201, 264, 265, 275, 277
Published work of Elizabeth Gertrude Britton, The 1
Puccinia 426; coronata avenae 428; graminis 62, 168, 378, 545; rubigovera 542; Sorghi 421; tomipara 542; triticina 378
Purdiaea 495
Pycnolejeunea 211; macroloba 208, 211, 264, 266, 277
Pycnophyllum 365
Pyracantha Pyracantha 228
Pyrola americana 484
Pythium 369; scleroteichum 423

Quercus 534, 535; alba 2, 483; velutina 483

Radula 270, 271; complanata 269, 271, 272, 280
Radulum 546
Ranunculus abortivus 480; acris 485; hirsutus 480; recurvatus 480; repens 482
Recent changes in the composition of a local flora 479
Recessive factor lethal for ascospore formation in Neurospora, A 117
REED, E. L., A new species of Ephedra from Western Texas 43
REED, GEORGE M., Inheritance of resistance to loose smut in hybrids of Fulghum and black Mesdag oats 177
Relation of chromosome pairing to fertilization, The 369
Remijia 223
Retama 223
Rhacopilum tomentosum 8
Rhapontica Rhapontica 229
Rhaponticum scariosum 229
Rhipsalis 499
Rhizobium 114, 549; Meliloti 114; Phaseoli 114; Trifolii 114
Rhizoctonia 359, 504; bataticola 500; Solani 109, 176; Zeae 175
Rhizopus nigricans 495
Rhododendron maximum 486, 488; nudiflorum 484; viscosum 482
Rhoeo discolor 429
Rhus toxicodendron 174
Rhynchospora confusa 231
Ribes 105, 346; floridium 481
Riccia 41, 108; canaliculata 40, 41; fluitans 33, 34, 38–42, 232; glauca 64; Heubeneriana 33, 40, 41; pseudo-Frostii 40; Sullivantii 40
Riccia fluitans L.—a composite species 33
Ricinus zanzibariensis 135
Robinia 114; Pseudo-Acacia 485
ROEVER, WM. E., Nuclear behavior in the tapetum of Hosta caerulea, with special reference to the divisions 345
Root rot, and Sclerophoma stem blight, of the Texas bluebell, Fusarium crown and 503
Roridula 170
Rosa 544; carolina 483; parviflora 483
Rubus 69, 483; idaeus aculeatissimus 483; occidentalis 483; parviflorus 295; setosus 486, 487; strigosus 483; trivialis 484; villosus 483, 484
Rudbeckia speciosa 165
Rumex Acetosella 485

Sabal louisiana 231
Saccanthus 60
Saccharomyces 110, 172, 237; cerviciae 355
Sagittaria latifolia 481; sagittifolia 481
Sahuaro Carnegiea 498
Salicornia 19
Salisburia adiantifolia 2
Salix 69, 534
Sambucus canadensis 483; racemosa 484
Samuela faxoniana 139
Sanguinaria canadensis 481
Sanicula marilandica 481
Saprolegnia 369
Sarcobatus 19
Sarcophaga 137
Sarcostemma viminale 175
Sarothannus 223; Adreanus 335; scoparius 335
Sarracenia laciniata 365
Sassafras variifolium 483
SATINA, SOPHIA and A. F. BLAKESLEE, Fertilization in the incompatible cross Datura Stramonium × D. Metel 301
Saurauia 430
Saxifraga pennsylvanica 482; tennesseensis 493; virginiensis 483
Scaevola 462

SCHAFFNER, JOHN H., Observations and experiments on sex in plants 387
Schilderia adamanica 167
Schistotega 6
Schizaea pusilla 6, 7
Schradera marginalis 59
Schraderobyrum 113
Scilla 95; bifolia 135
Sclerophoma 504–510; **eustomonis** 505–508, 510
Sclerophoma stem blight, of the Texas bluebell, Fusarium crown and root rot, and 503
Scolytus ventralis 550
Scouleria 5
Scrophularia marylandica 455, 464
Scutellaria cordifolia 482; galericulata 482
Sebacina globospora 432
Secale 144, 498; cereale vulgare 496
Sedum 359, 362
Selaginella 165, 547
Seligeria campylopoda 7; Doniana 7
Sematophyllum 7, 8; recurvans 8
Septoria acicola 175; Lycopersici 544
Sequoia 499
Sida spinosa 486
Silvia 493
Sirobasidium 342, 343
Sisyrinchium anceps 482; gramineum 482
Sium 462
Smilacina racemosa 480; stellata 482; trifolia 485, 487
Smilax herbacea 483
SMITH, ELIZABETH C., Effects of ultra-violet radiation and temperature on Fusarium. I. Lethal action 45; II. Stimulation 151
Solanum 222; Lycopersicum 229; nigrum 485; seaforthianum 174; Tuberosum 229, 497
Solidago altissima 481; canadensis 481; flexicaulis 481; rugosa 456
Solmsiella Kurzii 499
Sophora 222, 291
Sorghum 148
Sorodiscus 502
Sorosporium reilanum 431
Spartium 223
Spermatochnus paradoxus 496
Sphacelaria bipinnata 546
Sphaceloma 545; perseae 427
Sphacelotheca cruenta 429; Sorghi 429, 431
Sphaeralcea 494, 549
Sphaerocarpos 501, 539
Sphagnum 275, 369, 534; cuspidatum 275
Spinacia oleracea 135, 149, 376, 380
Spiraea latifolia 482; nipponica tosaensis 500; salicifolia 482; tomentosa 482
Spiranthes 490; cernua 481; gracilis 484
Spirogyra 369, 370, 379
Spirulina 364
Splachnobryum 9
Splachnum 6
Sporodinia 369
Sporotrichum Beurmanni 56, 58; Schencki 240
Stachys 233; tenuifolia aspera 482
Stagonospora Curtisii 430
Stangeria paradoxa 138, 147
Staphylococcus aureus 50, 53
Staurastrum stellatum 431
Steccherinum 546
STEINBERG, ROBERT A., The nutritional requirements of the fungus, Aspergillus niger 81
Steironema ciliatum 482
Stelis 165
Stellaria media 100
Stem blight, of the Texas bluebell, Fusarium crown and root rot, and Sclerophoma 503
Stemodia radicans 253, 254
Stereum sanguinolentum 494
Sterigmatocystis 47
STEYERMARK, JULIAN A. and THOMAS W. WHITAKER, Cytological aspects of Grindelia species 69
Stictolejeunea 195; Kunzeana 193–195, 198, 265, 277; squamata 194, 195, 277
Stilbum 431
Stomiopeltis Citri 360
Studies in the Ericales. I. The genus Gaylussacia in North America north of Mexico 129
Study of chromosome pairing in Yucca rupicola, A 133
Styrax 546
Symplocarpus foetidus 481
Synthyris schizantha 366
Syrbula 134, 148
Syrrhopodon parasiticus 13
Syzygites 369

TAFT, CLARENCE E., The Oedogoniaceae of Oklahoma including new species and varieties 281
Talinum 107, 233; calycinum 62
Taphrina deformans 296
Taraxacum officinale 485; Taraxacum 228
TAUBENHAUS, J. J. AND WALTER N. EZEKIEL, Fusarium crown and root rot, and Sclerophoma stem blight, of the Texas bluebell 503

Tautonyms, Additional notes on 227
Tavaresia grandiflora 544
Taxilejeunea pterogonia 208–210, 260, 262, 264, 265, 276, 277
Taxithelium 113
Taxodium distichum 232, 486
Taxonomic and climatic distribution of alkaloids, The 219
Taxus canadensis 534
Tecoma radicans 485
Ternstroemiopsis 494
Tetranychus bimaculatus 509
Tetraplodon 6
Tetrastrum 59
Teucrium canadense 482
Texas, A new species of Ephedra from Western 43
Thalictrum 388, 393, 399; dasycarpum 388, 392, 398, 400, 401; dioicum 388, 480; Fendleri 400; polygamum 400
Thamnobryum 12
Thelebolus 126
Thevetia Thevetia 228
Thielaviopsis basicola 165
Three new cuscutas 511
Thuidium 2
Thysananthus 201; amazonicus 199, 201, 277
Tibouchina 234
Tilia americana 484
Tilletia laevis 171; levis 496; Tritici 496
Tinantia anomala 91; fugax 92
Tomato fruits, A developmental analysis of size and shape in 243
Tournefortia 106
Tradescentia 91, 99, 100, 173, 346, 498, 539; anomala 91; erecta 92; Pringlei 91; virginiana 235; virginica 95, 99
Trametes Pini 172
TRELEASE, WILLIAM, A mislaid mistletoe 337
Tremella 342; lutescens 342
Tremellaceae, Atractobasidium, a new genus of the 339
Trichocolea tomentella 262
Trichoderma 240, 359, 504; lignorum 175
Tricholoma 218
Trichomanes radicans 7
Trichophyton gypseum 58
Trichosporium symbioticum 550
Trichostomum Warnstorfii 7
Trientalis americana 484
Trillium 376, 549; erectum 295, 480, 499; Ludovicianum 502
Tritelia Bridgesii 490
Triticum 144; vulgare 173
Trymatococcus 545
Tsuga canadensis 165, 483
Tuberculina maxima 363
Tubiflora acuminata 174
Tuomeya fluviatilis 3
TURNER, THOMAS W., The natural distribution of Cytisus scoparius in Virginia with special reference to soil reaction 331
Tympanis pinastri 425
Typha latifolia 481
Typhilla latifolia 481

Ugni Ugni 228
Ulmus americana 480; campestris 485; fulva 480
Ulota 5; americana 4; phyllantha 2
Ultra-violet radiation and temperature on Fusarium I. Lethal action, Effects of 45; II. Stimulation 151
Unifolium canadense 13
Uraspermum claytonia 484
Uromyces appendiculatus 378; Phaseoli typica 544; vignae 378
Urticastrum divaricatum 393, 398
Ustilago Avenae 177–180, 183, 185, 186; levis 177, 183, 185, 186; striaeformis 541; Tritici 168; Zeae 174, 295, 423
Utricularia 110, 296; Rendlei 296
Uvularia grandiflora 480, 488; perfoliata 297, 480

Vaccaria Vaccaria 227
Vaccinium corymbosum 482; dumosum 486; frondosum 486; pennsylvanicum 483; resinosum 484; tenellum 483; vacillans 483; virgatum 483
Vallea stipularis pyrifolia 60
Vallisneria spiralis 61
Vandellia 102; sessifolia 91
Vanilla Vanilla 227
Verbascum Thapsus 485
Verbena corymbosa 110; hastata 483; urticaefolia 483
Veronica agrestis 485; americana 482; anagallis 482; officinalis 484; virginica 482
Verticillium 169
Viburnum 61; alnifolium 110
Vicia 376, 498; faba 313, 454
Viola 69, 99, 100; cucullata 481; pubescens 481; riviniana 102
Viscaria Viscaria 228
Vitis-Idaea rotundifolia 175; Vitis-Idaea 227

Vittaria lineata 7

Wallrothiella arceuthobii 233
WATKINS, G. M., A study of chromosome pairing in Yucca rupicola 133; The relation of chromosome pairing to fertilization 369
Webera 6
Weissa 5
West Indies, The genus Cheilophyllum of the 253
WHEELER, LOUIS C., Euphorbia capitellata its synonymy and range 537
WHITAKER, THOMAS W. AND JULIAN A. STEYERMARK, Cytological aspects of Grindelia species 69
WHITEHOUSE, EULA, Notes on Texas phloxes 381
WILSON, L. R., The Nipissing flora of the Apostle Islands region 533
Wistaria 2
Wojnowicia graminis 499
Woodsia obtusa 541
WOODSON, JR., ROBERT E., The floral anatomy and probable affinities of the genus Grisebachiella 471

Xanthium 112
Xolisma 427

Yucca 133, 134, 138, 140, 143–148, 375–377, 380, 427; aloifolia 134, 135, 139, 149, 372, 373; angustissima 139; constricta 139; draconis 134, 135, 139, 140, 372, 373; elata 139; filamentosa 139; flaccida 139, 149; glauca 139, 147; gloriosa 134, 139; guatemalensis 134, 135, 139, 140, 372, 373; macrocarpa 139; recurva 139, 150; rupicola 133, 138–140, 147, 373–376, 432; Whipplei 109
Yucca rupicola, A study of chromosome pairing in 133
YUNCKER, T. G., Three new cuscutas 511

Zanthoxylum americanum 481
Zea Mays 240, 394, 399, 400, 544; tripsacum 495
Zephyranthes 403, 405, 544; bifolia 405, 406; carinata 404, 405, 408; citrina 403, 404, 408; Eggersiana 403, 404; robusta 405, 408; rosea 405, 406, 408; Tubertiana 405; Tsouii 404
Zephyranthes, Duplications in 403
Zeugites munroana 170
Zingiber Zingiber 228
Zizania 544
Zostera 111, 367; marina 361, 429
Zygodon 9

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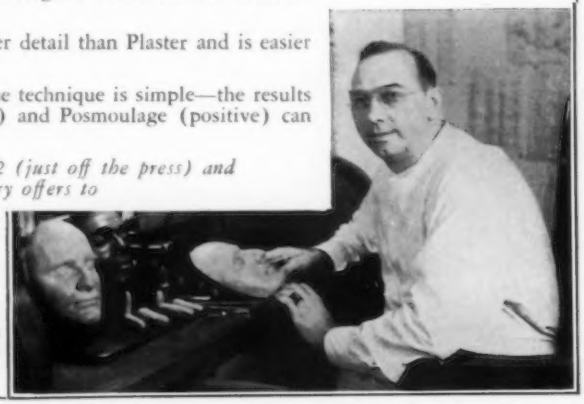

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